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- The Hydrogen Bomb Exploded?
- Parliamentary Debate on Science
- Effects of High Pressure

he Role of ig Telescopes
DAVID S. EVANS, M.A., Ph.D.

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SIR EDWARD APPLETON, F.R.S.

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# DISCOVERY

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The Progress of Science

The Hydrogen Bomb Exploded?

THE impression has been given to the public that if it ever proves possible to make a hydrogen bomb then this weapon will render obsolete the plutonium bomb, on the grounds that the nation which produces hydrogen bombs will be militarily stronger than if it concentrated its 'atomic' war effort on the production of 'fission bombs'. (The latter term is a convenient term covering uranium and plutonium bombs, both of which derive their explosive force from a fission process as opposed to the nuclear syntheses involved in the hypothetical hydrogen bomb.) But this idea is questioned in the May issue of *Scientific American* in an article by Dr. Robert F. Bacher, professor of physics at the California Institute of Technology, who is particularly well qualified to speak on this subject because of his experience on the wartime atomic bomb project and his membership of the U.S. Atomic Energy Commission from 1946 to 1949. He expresses very strong doubts about the military usefulness of a hydrogen bomb; for military purposes he thinks it would be considerably too powerful, and likely to 'over-saturate' any target one can envisage. Dr. Bacher appears to be convinced that nothing larger than a fission bomb is militarily useful; 25 fission bombs would thoroughly destroy any metropolitan area, he says, and possibly the figure would be as low as 10. "It also appears that two atomic bombs would completely paralyse a city, even a large one," he says. He considers that if America had a thousand fission bombs it could outclass any potential enemy, calculating that 1000 bombs would go a long way at the rate of 10 for each major metropolitan area and perhaps a smaller number for major cities. With a stock of a thousand bombs he reckons there would be "a great many to spare for relatively minor military objectives," and adds, "I imagine that the military commanders would have a hard time figuring out what to do with the last hundred." Dr. Bacher makes it clear that he considers tritium as well as deuterium would be needed to make a hydrogen bomb. The preparation of that tritium could only be done using an atomic pile, and Dr. Bacher seems to be convinced that the neutrons diverted to tritium manufacture would be better employed in plutonium production. He underlines this by saying "it is a point worth emphasising that tritium could be produced only at the cost of using neutrons that might otherwise be employed to make plutonium."

Incidentally in the course of this very well argued article, Dr. Bacher produces one excellent analogy to explain the principle of the hydrogen bomb which is worth quoting. This is what he says: "The real problem in developing and constructing a hydrogen bomb is: 'How do you get it going?' The heavy hydrogens, deuterium and tritium, are suitable substances if somehow they could be heated hot enough and kept hot. This problem is a little bit like the job of making a fire at 20 degrees below zero in the mountains with green wood covered with ice and with very little kindling. Today scientists tell us that such a fire can probably be kindled with the heavy isotopes of hydrogen. Once you get the fire going, of course, you can pile on the wood and make a very sizable conflagration. Similarly the hydrogen bomb could be built up with more heavy hydrogen. It has been called an open-ended weapon, meaning that more materials can be added and a bigger explosion obtained."

Parliamentary Debate on Science

ON May 5 the House of Commons spent most of the day debating the following motion: "That in the opinion of this House, there should be the fullest development and utilisation of Britain's exceptional scientific resources and manpower, with a view to ensuring effective progress in the development of our industry, agriculture and Colonies, and a material improvement of our economic position in the world." It was a stimulating debate, and generally well informed. It was encouraging to listen to Mr. Herbert Morrison replying for the Government for it was clear that in the present Lord President of the Council we have a man who is eager to see that scientific research receives all possible support from the Government and who clearly realises the contribution that science can make to the improvement of Britain's economic position.

The best contributions to the debate, as one might have expected, came from those M.P.'s whose professional careers bring them in direct contact with scientific matters. For example, a brilliant statement of the case for paying

technical teachers higher salaries was made by Mr. Orr-Ewing, who was a governor of the Northampton Polytechnic before he was elected M.P. for N. Hendon. He started by giving a useful analysis of figures for scientific personnel in Britain; quoting Sir Ben Lockspeiser, head of the Department of Scientific and Industrial Research, he said there are about 60,000 science graduates in the United Kingdom, of whom about 50,000 are employed directly on scientific subjects. This number he suggested is distributed as follows: 25,000 are employed in teaching in universities, technical institutes and schools; the scientific Civil Service employs about 5000; 800 are in public bodies like the Coal Board; the Research Association employs 1000, and industrial firms have about 8000 engaged on research. The remainder—10,000 of the total—he said are distributed over the whole plane of development and industry. In the competition for personnel at this time when demand for scientists and technologists outstrips the supply, the schools came off extremely badly. The fact that salaries for science and technical teachers are low compared with those paid elsewhere Mr. Orr-Ewing showed convincingly to be the reason why teaching in schools and technical colleges was failing to attract adequate numbers of science graduates. He quoted from his personal experience of what had been happening at Northampton Polytechnic. He said that long before graduation many of the students secured contracts with industrial firms, which paid as much as £550 a year shortly after graduation. He mentioned the case of a student who gained a pass degree last June, and who was earning £550 in industry by August. Three months previously he had been receiving tuition from instructors in the college who were paid considerably less—even less than £400 a year. Mr. Orr-Ewing criticised the Burnham Scale, which gives a graduate £396 a year in the London area, and less in the provinces. After ten solid years of teaching such a graduate would get about £550—the figure which an inexperienced graduate with only a pass degree can get in industry immediately on leaving the university or technical college. The Oxford University Appointment Committee found that over the years 1945–1949, only 46 out of 197 science and mathematics graduates went into teaching —and of those only 42 remained in the teaching profession. "The position in technical and grammar schools is desperate," said Mr. Orr-Ewing. A recent survey showed, for example, that of 790 grammar schools 49 found it absolutely impossible to secure a master to teach physics and chemistry *and had dropped science altogether from the curriculum.* This is quite obviously a matter demanding immediate attention and very prompt action if Britain is to maintain her position in this age of science. As Mr. Orr-Ewing put it: "The whole of our scientific structure rests on a foundation which is the instruction which we can give in our schools, technical colleges and universities. If we do not pay first attention to that foundation, we are forfeiting its future and also the future of our country."

Another fundamental matter which was discussed was the question of how to secure the maximum use of science in small firms, a question of considerable importance since 25% of British production comes from firms employing fewer than 100 people. Mr. Carr (M.P. for Mitcham) pointed out that it is a wasteful process to encourage small and even medium-sized firms to continue taking on more and more scientists and starting up new laboratories and so forth. Far the best method for such firms is co-operation in the activities of Research Associations.

The demand that Britain should set up institutions equivalent to the Massachusetts Institute of Technology and the Zürich Polytechnic has received such powerful support in all interested quarters that a definite decision from the University Grants Committee on this issue must surely come before long. It was quite evident from the debate that Parliament as a whole favours the establishment of such an institute or institutes to give higher education in technology.

The Lord President of the Council replied to the debate. He touched on the question we have just mentioned, and assured the House that the idea of establishing a British Institute of Technology was not being neglected. He was somewhat cautious on the subject, and said that "if further action does not follow as fast as some would wish it is due to the complexities and difficulties of shaping the right measures in the light of our special needs and our limited resources, and not to any failure by the Government to appreciate the importance and the urgency of the task." He mentioned the Imperial College of Science and Technology in London, the Manchester College of Technology and the Royal Technical College, Glasgow, and said these could certainly be built up into technological universities.

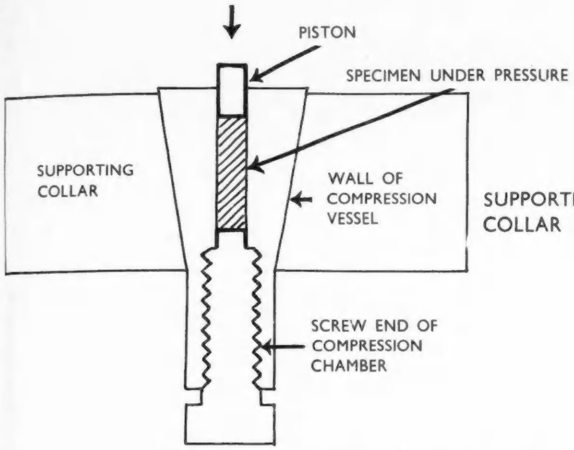
Scientists in general, and the Royal Society in particular, have called for a scientific centre in London to be established with adequate accommodation for the leading scientific societies. Mr. Morrison referred to this, and said: "I believe that if we can house in the same building the three great research bodies—the D.S.I.R., the Medical Research Council, and the Agricultural Research Council—the Royal Society and a number of other scientific and learned bodies and make a really great centre of science on a worthy site in London, it would be a great thing and well worth doing. We all live with Finance Ministers, and my right hon. and learned friend the Chancellor of the Exchequer has his troubles; but in principle the idea is accepted, both by the Royal Society and others, and by the Government, and we hope to proceed with it at not-too-distant a future. Indeed, the Government have already promised to help in finding a site for this project."

The full debate (reported in *Hansard*, Vol. 474, No. 41), is worth studying, and anyone who has a scientific point which he feels needs ventilating in Parliament has only to glance through the various speeches to see that there are several M.P.'s sympathetic to any reasonable approach on a reasonable topic who could raise the matter in the House.

Effects of High Pressure

MANY people must have been set wondering when they first learned of the modern theory of matter. There is the relatively enormous amount of empty space between the nucleus and the electrons in any atom; there is the empty space between atoms in a crystal lattice—the geometrically symmetrical and rigid arrangement that is the unit of any crystal form; there is the amazing fact that this crystal exists at all. There is the peculiarity of space existing between molecules in a liquid, space big enough to admit molecules of a substance that is dissolved in the liquid.

One question has doubtless arisen in many minds, usually to be dismissed at once as only the specialist knows



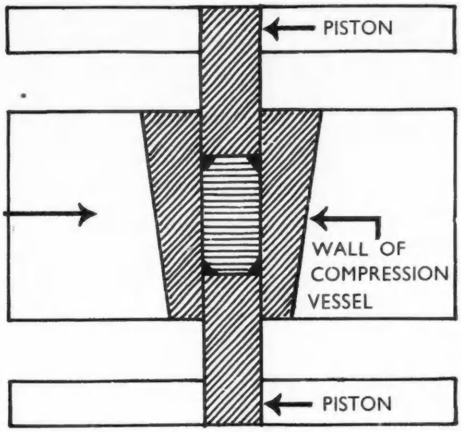


FIG. 1 (*Left*).—Vertical section of apparatus for getting pressures up to 50,000 atmospheres. The material to be compressed is shown cross-hatched. The pressure is applied to the piston in the direction of the arrow. The conical exterior of the compression vessel causes an external pressure to be exerted on it that increases as the pressure on the piston increases; the vessel is surrounded by a stout steel collar to prevent cracking of the vessel. This is a schematic diagram, not to scale, and leaves out devices for preventing leakage, etc.

FIG. 2 (*Right*).—This simplified diagram shows the principle of the apparatus for getting pressures up to 100,000 atmospheres when immersed in a liquid under a pressure of 30,000 atmospheres. The parts hatched with oblique lines are made of Carboloy. That hatched horizontally is the specimen to be compressed. Parts not hatched are of steel. A pressure of nearly half a million atmospheres has been produced using this apparatus.

where to start looking for the results of researches with a bearing on this question. That question is: What will happen to matter in the liquid and solid state, consisting so much of empty space, when it is subjected to extremely high pressure?

To this question Professor P. W. Bridgman of Harvard, who recently visited this country and delivered the Bakerian lecture to the Royal Society, has devoted himself for more than forty years. When he summarised existing knowledge in the realm of science up to 1931 in his book *The Physics of High Pressure*, he gave 204 references to literature on this subject, past and contemporary. In his summary published in *Reviews of Modern Physics* in 1946, there were 674 references, all more or less contemporary. This is measure of the increase in interest of the subject among scientists in the last fifteen years, an increase almost entirely due to Prof. Bridgman's influence. Centres for research on the problems associated with very high pressure now exist in Holland, France, Russia, and England, as well as in Prof. Bridgman's own laboratory at Harvard University.

The classic researches of the past were done by the French physicist Amagat, who succeeded in creating pressures as high as 4000 atmospheres. Prof. Bridgman has obtained reliable *quantitative* results at 100,000 atmospheres, which is close on 700 *tons to the square inch*. This is the extreme limit of reliable practical achievement so far, but it is a long way off the pressure at which it is computed that matter would become disintegrated to form a gas composed of fundamental particles. (One worker has calculated that at a thousand billion atmospheres, all electrons would cease to be attached to nuclei and behave as a gas; another has calculated that a hundred million times that pressure would be needed to convert matter into a neutron gas.

In devising apparatus for his experiments Prof. Bridgman has shown great ingenuity, as might be expected from one who says with the justifiable and humble pride which typifies the keen experimenter that he has always been accustomed to working with his hands. How can a high pressure be produced? First the prime source is a hydraulic press. Then if the force available is made to act over a very small area, the actual pressure in pounds per square inch (one atmosphere being about fifteen pounds per square inch) can be made high. So the amount of material to be compressed must be quite small, and the obvious thing to do is to put it into a metal cylinder of small bore and then press on it with a piston. The limit is set in such a cylinder by the tensile strength of the material from which it is made. For steel this used to stand at about 15,000 atmospheres, but today steels are available with a tensile strength of some 23,000 atmospheres. Another limit is set by the pressure at which the piston begins to flow and undergo distortion under compression. For steel this pressure is about 30,000 atmospheres, but for a special alloy called Carboloy, used to a great extent by Prof. Bridgman, it is some 67,000 atmospheres. The cylinder itself can be restrained and thus enabled to withstand higher pressures, but the limit is then set at the flow point of the inner wall. To achieve quantitative and reliable results with pressures over 30,000 atmospheres, the device of Fig. 1 has been used, wherein the container itself has a conical shape on the outside. Then as the piston presses inwards the pressure is transmitted to the wall and the cone is forced inwards thus increasing the external force on the outer surface. With this apparatus Prof. Bridgman has achieved a pressure of 50,000 atmospheres with an internal diameter of a quarter of an inch. Another device is to immerse the apparatus in a liquid under hydrostatic pressure up to 30,000 atmospheres. He found that when

this was done the steel and Carboloy changed their properties. The latter lost its brittleness and had a higher tensile strength. The apparatus shown in Fig. 2 could then be used up to 100,000 atmospheres, and by making the specimens to be subjects for the extreme compression very small indeed he even reached 425,000 atmospheres.

Of course, the precise shape and dimensions of the apparatus used varies with the nature of the experiment, and there are many details of procedure—how to prevent leaks for example—that are essential knowledge for anyone intending to work in this field. In addition, the changes that occur in the substance have somehow to be observed and measured, whether by window, or by connecting the specimen to electric measuring instruments by wires led into the compression chamber, or by some other device. The tiny compression chamber, only half an inch wide in the bigger type of apparatus, is in fact a miniature laboratory in itself, and measurements have to be made in it directly or indirectly.

The actual measurement of the high pressures applied to that degree of accuracy necessary for fundamental research is also a problem. Any pressure could, of course, theoretically be measured by applying it to the mercury in a cistern holding a vertical tube, just as is done for measuring normal atmospheric pressure in the mercury barometer. But for even moderately high pressure, such as 30,000 atmospheres, the tube would have to be nearly a million inches, or some twenty miles, high. (Amagat, one finds, did actually contrive to make use of the great height of the Eiffel Tower in his experiments.) Devices like the Bourbon spiral-tube gauge can be used only up to 3000 atmospheres. The free-piston gauge, wherein the pressure is measured by the weight applied to a freely moving piston connected with the source of pressure, can with care be used up to pressures of 13,000 atmospheres. A more useful method for higher pressures, as developed by Prof. Bridgman, is to measure the change in electrical resistance of a conductor such as manganin. Even here, great care in detail is necessary—Prof. Bridgman has a coil of manganin wire (of unknown German origin and bought more than thirty years ago), and all his high-pressure gauges are made of wire from this one coil; his attempts to use new manganin made in the U.S.A. proved unsuccessful.

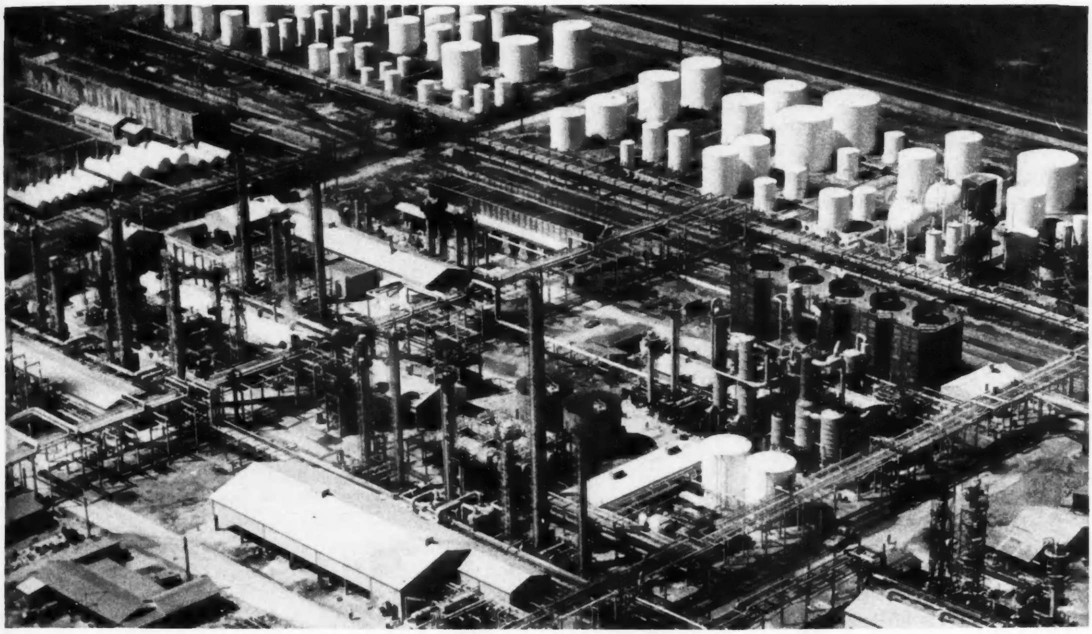
Although most of his results—and those of other workers—are of importance chiefly to fundamental science, there are some with bearing on industry and others that are of general interest. Among the more fundamental results are the data now available on the compressibility of hundreds of substances. This, in general, gets less as the pressure increases, a result in keeping with the concept that atoms and molecules are forced nearer to each other against the repulsive forces keeping them apart. On the whole the tendency is for the compressibility of compounds which have the most atoms to the molecule to decrease the most rapidly. In connexion with crystal structure, results for salts compressed up to 50,000 atmospheres and metals up to 100,000 atmospheres are in agreement with Prof. Max Born's theoretical calculations. The internal friction (viscosity) of a liquid increases with the pressure, and new theories of viscosity have found verification from the results of high-pressure experiments. When the relative change of volume is plotted against pressure on a graph, the curve for many substances is a smooth one rising sharply at first and then bending over to become more nearly horizontal. But for some substances there are sudden sharp discontinuities. These correspond to changes of form, whether in the crystal lattice or the atomic conformation. Bismuth suffers one of these sudden 'polymorphic' changes at a pressure of about 25,000 atmospheres, and this is so well marked that the transition can be utilised as a secondary gauge for measuring the pressure. At still higher pressures, some of the sudden transitions have been associated by theoretical physicists with changes in the energy-levels of electrons.

In addition to these fundamental aspects of the results there are many interesting changes to record. Cement, for example, increases in compressive strength with a rise in pressure, and steel under high pressure becomes more ductile. Prof. Bridgman has even produced totally new forms of matter. He has changed white phosphorus at 35,000 atmospheres into a new form, black crystalline phosphorus, which is afterwards quite stable under normal conditions. At a pressure above 40,000 atmospheres and a temperature higher than 175°C., the liquid carbon bisulphide slowly polymerises (i.e. its molecules join together) and changes into a black solid that is indefinitely stable at room temperature. A number of colour effects have been observed when minerals are subjected to high pressure. Thus yellow calcite turns a 'light bluish grey' and green fluorite becomes violet. These colour changes are attributed to distortions in the crystal lattice. Combinations of high temperatures and pressures are of tremendous interest to geophysicists, for they provide the only experimental evidence of processes believed to have been going on in the earth's crust. Prof. Bridgman has already succeeded in changing opal into quartz by the application of high pressure.

Workers on very high pressures have investigated mechanical, thermal, electrical, magnetic, optical, chemical, and biological effects, some of which have already been mentioned. Among the chemical effects is the increased speed of chemical reactions that are slow at ordinary atmospheric pressure. And chemical compounds undergo changes at extremely high pressures; thus suboxide of lead, usually black, turns greyish blue and then grey at 3000 atmospheres, and at 12,000 atmospheres it has a metallic lustre caused by the presence of free flakes of lead; in this case the pressure has effected a chemical reduction from lead oxide to lead.

Many experimenters have worked in the biological field, especially in finding the effect of high pressure on viruses and bacteria and small organisms. The active principle of some tumours has been found to be inactivated by a pressure of 1800 atmospheres, yet some bacteria can survive pressures higher than that. An example is *Bacillus subtilis*, one of the fermentation bacteria found in the human gut; this bacillus has survived a pressure of 17,500 atmospheres. The tiny slipper animal *Paramecium*, which consists of a single cell (though it is rather more highly organised than an amoeba), can withstand a pressure of 800 atmospheres without suffering an irreversible change. Milk bacteria can be killed, and the milk thus sterilised, at pressures between 3000 and 7000 atmospheres.

The work on very high pressures continues to expand in all fields. This enormous interest can be attributed largely to Prof. Bridgman's example. For his work of forty years he was awarded a Nobel prize in 1946.



Glycerine from Petroleum

IF, on a summer's day, one leaves the industrial beehive known as Houston, Texas, and drives to the east along the La Porte Highway, there is never the slightest doubt that one is travelling in the U.S.A. An observant motorist can see an almost continuous stream of roadside evidence testifying to American folkways. Numerous new and expensive cars, quite often inexplicably laden with people in poor and shabby dress, flash by over the spacious concrete highway, which stretches far ahead, straight and level as a great yardstick for measuring the steaming prairie. Of course, the usual hot-dog stands, neat and often even artistic gas-stations with polite attendants, and movie-houses, are not absent from the roadside evidence. Now and then one passes an attractive group of homes, but often the eye lights on dismal dwellings that seem to have been erected after only negligible forethought by highly individualistic mechanics. But, nevertheless, and this is more important for our present account, there very frequently juts up above the flat horizon a magnificent outdoor chemical plant, which was evidently preceded by a great deal of the most careful kind of reflection. And there it stands in the blazing sun, with all its process units resplendent in their silvery coats of heat-reflecting paint.

The mild winter climate is one of the important reasons for the rapid industrial growth of this area, as construction and maintenance costs are definitely less here than in the more rigorous north. Pipes exposed to the elements seldom freeze in this part of Texas. Another important reason is a plentiful local supply of petroleum to feed the burgeoning petro-chemical industry, of which Houston is an important centre.

After about twenty miles of this journey, which was punctuated by three sudden rain squalls of almost tropical intensity on the afternoon when the writer made it, one comes to a small and easily missed sign marked 'Deer Park'. The spot belies its quaint name. The landscape just described continues ahead of the motorist in an apparently endless line, and on the right stretches the raw prairie. But on the left rise the grotesque metal towers of the first synthetic glycerine plant in the world, the creation and property of the Shell Chemical Corporation. In a bristling field of about seven acres stands a planned tangle of great reactors, evaporators, condensers, centrifuges, a maze of piping and electrical equipment, and all the rest of the queer-looking paraphernalia the modern engineer assembles when he undertakes to teach Nature a thing or two about chemical synthesis; he does in an $8,000,000 plant and starting with a hydrocarbon gas what a contemplative cow does rather more quietly and simply, starting from blades of grass. Still it is a bold and Promethean venture for man to undertake to duplicate a natural compound by unnatural means.

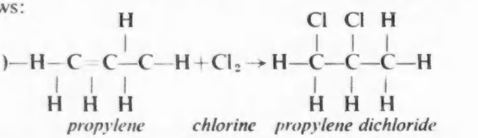
For many years and in every corner of the world, mankind has used glycerine, but it was heretofore almost entirely derived from animal fats. It was widely produced either as the by-product of soap-making (and hence it is called 'saponification glycerine') or as a product of the fat-splitting industry. In war-time, under pressure of military needs for nitroglycerine, minor amounts of glycerine have been made by fermentation methods. For more than a century glycerine derived from animal fats has been an important commercial product, and today in more than fifteen hundred ways it fills certain requirements of mankind. The sweet, odourless, syrupy and slightly intoxicating compound has long served to help with man's entrance into this world, has smoothed his passage through

it in many ways, and too often, in the form of explosive nitroglycerine, it has hastened him out of it. An entirely new method of manufacture is consequently of considerable interest. Therefore let us turn in at the Deer Park plant, and see how the synthesis of the useful substance called glycerine is commercially accomplished to the tune of about three million pounds a month.

First of all, a large and continuous supply of propylene is supplied to the Deer Park chemical plant from the oil refinery which is adjacent. Propylene is a hydrocarbon gas, the molecules of which are composed of three carbon and six hydrogen atoms; it is an unsaturated compound, there being a double bond between two of the carbon atoms. This gas is normally found in large amounts in the cracked gas mixture that issues from the great catalytic cracker in that refinery. If propylene were not used to make glycerine or certain other petroleum chemicals, it might be much less advantageously consumed as an excellent gaseous fuel.

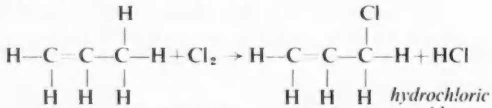
The first step in making a pure, bland, and sweet product fit for human consumption out of such an unappetising material as a cracked petroleum gas calls for the combination of propylene with chlorine gas to form allyl chloride. As we shall see, this is something that is much easier said than done. But when it was done, and here research showed the way during about twenty years of work, the most difficult theoretical obstacle to synthetic glycerine was solved; because it has long been known that once allyl chloride is obtained glycerine can be readily made from it.

However, it did not prove an easy task to persuade propylene to react with chlorine to form allyl chloride. Propylene contains a double bond, and the natural tendency is for chlorine to *add on* at the point of unsaturation; that is to say, chlorine would normally *combine* with propylene at the double bond rather than *substitute* itself for one of propylene's hydrogen atoms. The normal reaction that one would expect at room temperature is as follows:

(1) 

This addition product would be worthless for glycerine synthesis.

The object of early Shell research was to find the conditions that would cause the following substitution reaction to take place, so that the double bond would remain for valuable subsequent reactions.

(2) 

All the text-books agree that the odds are all in favour of the reaction involving formation of propylene dichloride as in Equation 1. The proper conditions to obtain the results expressed in Equation 2 were not easy to ferret out.

If the reader will pardon a somewhat outlandish analogy, Equation 1 may be likened to the now old-fashioned behaviour of a rich Turk when he added a new member to his harem while retaining all the older and rather more grizzled members of his menage. It was a simple addition reaction. On the other hand, Equation 2 may be considered a modern version of the same basic urge expressed in the startling manner of Hollywood cinema stars. It is a substitution reaction. In the movie capital a new spouse is regularly substituted for a previous one, who is thereupon released from all allegiance, while a very active centre of interest—the double bond—is retained for subsequent reactions of a similar kind in the not-far-distant future.

After a great deal of basic research the proper conditions were established for forming allyl chloride in excellent yield. It was found that propylene can be chlorinated in the manner desired by operating at elevated temperatures (between 500 and 600° C.) in the absence of a catalyst. Yields of allyl chloride as high as 85% can be obtained. A temperature rise above the range limit must be avoided because excessive thermal decomposition of the newly formed allyl chloride follows.

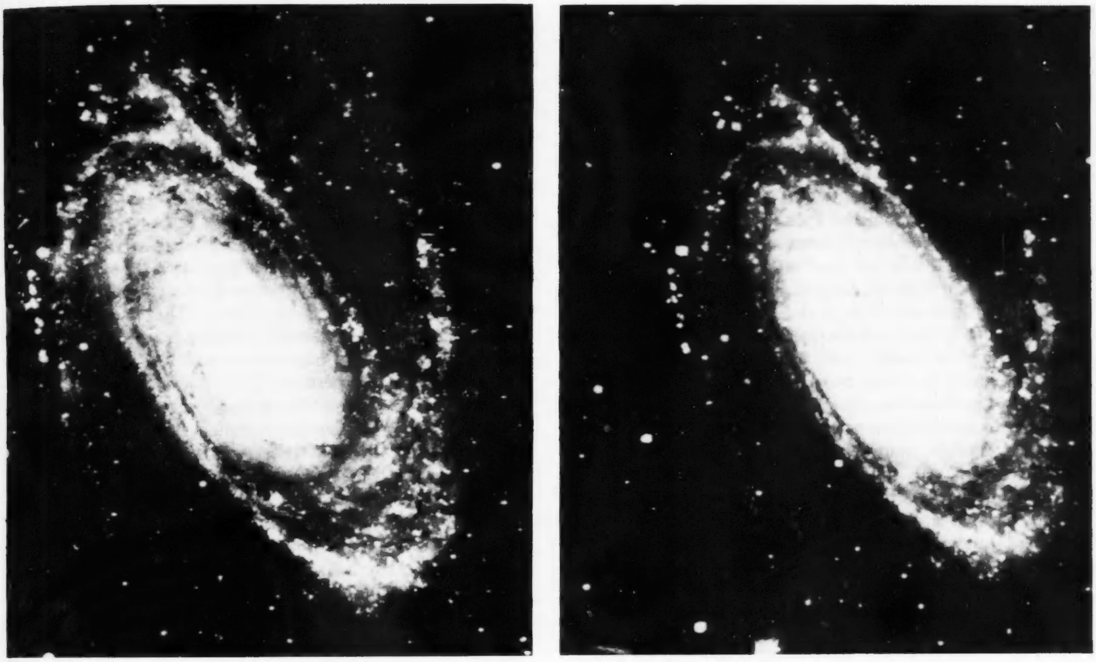
The allyl chloride is freed from hydrochloric acid by water-scrubbing, and is then treated with caustic soda, chlorine, and water through one or the other of two series of reactions that finally terminate in a dilute solution of crude glycerine.

The dilute solution of glycerine thus produced contains a good deal of water, some sodium chloride, and a number of other chemical compounds in very small amount. When these are removed by proper evaporation, settling, and distillation procedures, a final water-clear product containing more than 99% of glycerine is obtained and ready for the market.

Of course, a great many other problems of proper acidity, optimum pressures, and satisfactory equipment design to increase efficiency and avoid corrosion had to be solved in twenty years of laboratory research and ten years of pilot plant study before the method became commercially feasible. The research and pilot plant work were successfully concluded before the recent war, but unfavourable economic conditions and war-time shortages of necessary materials postponed construction of the Deer Park plant until 1948. It was found that equipment made of nickel and nickel alloys successfully resisted many of the most corrosive steps in the process and is essential to its success. The final pure glycerine product is shipped in railway tank cars of aluminium.

The largest peace-time consumers of glycerine are the producers of synthetic resins (who use them for making many kinds of surface coatings and plastics), the tobacco industry, the dynamite manufacturers, and the cellophane makers. Glycerine is also important for the processing of foods because it sweetens the product, and also acts as a preservative; when glycerine is used in candy, for example, it gives a longer shelf life, and in salad dressings it retards oil separation. The humectant properties of glycerine serve to keep tobacco fresh and sweet-tasting. It is also widely used in the preparation of medicines, pharmaceuticals, cosmetics, and in the manufacture of such familiar articles as cough drops, tooth paste, shaving cream, and toilet soap. More than 1580 uses were listed by patient recorders a few years ago, but this list is said to be already out of date. The development of the synthetic process creates a big additional supply of glycerine to meet its increasing demand.

WILLIAM D. MOGERMAN



These two pictures give a good impression of the amount of extra detail revealed by the 200-inch telescope. Both pictures are of the spiral nebula Messier 81. The one on the left was obtained with the 200-inch telescope on Mount Palomar; the right-hand picture was taken with the 100-inch on Mount Wilson.

The Role of Big Telescopes

DAVID S. EVANS, M.A., Ph.D.

BIG telescopes are in the news. For instance, in a recent issue of the *Proceedings of the Astronomical Society of the Pacific*, Dr. E. Hubble, one of the leading figures in the 200-inch Palomar telescope project, has presented photographs taken with this instrument, and the first observational results from the recently completed Radcliffe telescope at Pretoria, Union of South Africa, have begun to appear. The 98-inch disk for the large telescope of the Royal Greenwich Observatory at Herstmonceux has recently arrived in Britain. The construction of a 76-inch telescope for the French observatory at St. Michel, situated in a deserted part of the country not far from Marseilles, has been given prominence. Instruments of 74 inches diameter are in course of construction for the Commonwealth Observatory of Australia at Canberra, and for the observatory at Helwan in Egypt.

What immediate material benefit could conceivably result from work done with these telescopes ?

The question may be answered by putting another one. "What powers do these telescopes possess which other instruments lack?" The first and most obvious feature of large telescopes is that they are large: the mirror of a telescope is a collector of light and the larger the mirror the more light it can collect from a given source. Twice the diameter means four times the light collecting area. Dr. Hubble reports that the full theoretical magnitude gain of the 200-inch over the 100-inch telescope has been secured.

Merely to collect light is, however, not enough; the collected light must be concentrated. The concave surface of a telescope mirror reflects the incident light and brings it to a focus, producing on a photographic plate an image of a star which is almost—but not quite—a point. The size of the stellar image is the product of a great many different causes: the quality of the mirror, the steadiness or unsteadiness of the air through which the starlight has passed, the accuracy with which the telescope has been kept pointing at the selected star; these are only three of many relevant factors. It is essential to secure an optimum for each of these separate conditions if the highest efficiency is to be obtained. Most of the advantages of increasing the size of a telescope will be lost if at the same time the size of the point into which the reflected starlight is packed by the mirror is also increased. It is thus necessary to maintain and if possible improve the accuracy of figure of the reflecting surfaces of mirrors as larger and larger ones are made. Merely to double all the dimensions would be a waste of effort if at the same time minute errors were enlarged.

But, if large mirrors are made with the necessary accuracy, if they are mounted in mechanical arrangements of great efficiency, and if the resulting telescope is placed

on a site where the atmospheric conditions are as good as can be found, then each increase in size will mean a gain in faintness of the faintest possible star which can be photographed. Or, as an alternative, photographs down to the same limit of faintness can be secured in a far shorter time.

The large telescope opens up a whole new set of faint stars to observation; or, if the collected starlight is to be fed into a spectroscope, the increase in size of telescope enables the spectra of fainter stars to be obtained. In direct photography the role of the large telescope is thus to extend the range of stars accessible to observation, whether they are members of general star fields, or whether they constitute the fainter stars in clusters; in spectroscopy, the large telescope can help to make available for examination and analysis stars lying beyond the present brightness limits. In spectroscopy there are two limiting demands: the demand to obtain a spectrum of *some* kind, of very faint stars; and the demand to obtain a spectrum revealing greater and greater detail of any given star. In the formation of a spectrum the light from a star is spread out into its constituent colours, and, roughly speaking, the more it is spread out the more detailed and revealing can the analysis of the spectrum become. It follows, then, that a spectrum is obtainable only for stars a good deal brighter than the limiting magnitude accessible in direct photography. Spectra of the highest dispersions can only be obtained, even with the largest telescopes available, for relatively very bright stars.

Two sample problems will set the picture more exactly. Because of their great interest for problems of stellar structure and evolution, the type of intrinsically very faint stars known as white dwarfs is regarded as very important. These stars are the small, almost planet-sized, hot, fantastically dense, stars of which the companion to Sirius is the prototype. White dwarfs as a class are probably some 2500 times fainter than the sun, and even at the distance of the nearest star a white dwarf would only be just visible to the naked eye. Space is possibly quite full of white dwarfs, but their intrinsic faintness makes them most difficult to identify and only rather few are known. Certain identification is only possible when a spectrum is available. Clearly, then, a large telescope with a spectroscope attached is necessary to enable astronomers to extend the class of known white dwarfs.

But to obtain a real understanding of the physics of stellar atmospheres, spectra of the highest quality and showing all the fine detail are necessary. Even with the brightest stars one cannot have too much light for this type of study, so that again the large telescope is a necessity.

So far we have merely concerned ourselves with the light-gathering capacity of the large telescope. It has a number of other features which we must discuss in turn. The first is *resolution*, or the capacity for revealing detail. Which is preferable, to have a telescope which produces a large-scale picture of a piece of sky, or to have a telescope which only produces a small-scale picture, but to enlarge the picture, or to examine it with a microscope, afterwards? At first sight one might think that the two processes gave the same result. In fact they do not, and two considerations are involved in the resultant differences.

The scale of the picture depends solely on the focal length of the instrument and not at all on its diameter. A telescope with a focal length of 30 feet will produce a picture having twice the scale of the picture produced by a telescope of 15 feet focus. The scale will not be affected in the least whether one instrument has a mirror a foot in diameter, or 2 feet, or an inch. On the other hand, the image will show finer and finer detail as the diameter of the main mirror is increased. If, for example, we have a telescope with a mirror 1 foot in diameter it may show a single star at a given position. A telescope of 2 feet in diameter and the same focal length may show that same star as slightly elongated. A telescope 4 feet in diameter may show that in fact there are two stars present lying very close together. That is to say, that although the scale of the picture may be the same in these three cases, there is more intrinsic detail in the picture produced by the largest mirror. Provided that the photographic plate employed has enough resolution, it becomes more and more worth while to enlarge the resulting photograph or to examine it with a microscope, the bigger the telescope employed. On the whole, large telescopes do not produce bigger pictures of the same area of sky—often the reverse is the case—but the pictures are better *because more detail can be got out of them.*

The large telescope scores, for example, in studies of the structure of nebulae and clusters and also in studies of detail on the surface of planets. What may have been seen hitherto only as a blob of light or a smudge of darkness may now reveal itself as a structure from which a meaning can be extracted. A good example of the way in which the large telescope has scored in the field of nebular studies is afforded by work done, particularly with the 100-inch telescope on Mount Wilson, on the structure, internal motions and distances of some of the nearest nebulae, which are sufficiently near to us and of sufficiently large dimensions to be seen as objects having a well-developed internal structure.

The large aperture telescope enables a large effective image scale to be obtained, without necessarily having a large image, and indeed, since the scale of the image depends on the focal length, there are considerable advantages in keeping this as small as possible. A long telescope is mechanically awkward. It needs a long tube structure which may involve problems of strength, weight and vibration; it needs a large dome in which to house the instrument, and this puts up the cost of what is, after all, not the telescope itself, but only an accessory. But there are more fundamental advantages than this. Provided the diameter of the instrument is large enough to give all the resolution required, everything is to be gained by reducing the focal length. Now, since the scale depends on the focal length, the image of an extended object, such as a nebula, gets more spread out as the focal length increases. On the other hand, the total light available to form the whole image goes up as the area of the mirror is increased, i.e. as the square of the diameter of the mirror. A prime difficulty in almost all photographic astronomy is to get enough density on the photographic plate, and clearly the way to do that is to increase the diameter of the mirror—which collects a lot of light and gives high resolution in the image—while at the same time keeping the focal length as small as possible in order not to waste the light by spreading it out too much. If, in the end, we want a large impressive picture showing a great deal of detail, we can always get it by making an enlargement from the final plate. The key quantity in this argument is the focal ratio of the telescope

—the ratio of the focal length to the aperture. For most large telescopes the value is about 5.

To see how important the focal ratio is, we have only to consider the fact that a Newtonian telescope with a focal ratio of 4 would be one and a half times as fast as one with a focal ratio of 5 (the exact figure is $5^2/4^2 = 1{\cdot}56$, as the speed is inversely proportional to the square of the focal ratio).

This means then, that, just for taking a photograph of a nebula, an ordinary hand-held 35-mm. camera working at f/3·5 is faster than the 100-inch telescope. The small camera will produce a picture of the same object more quickly, provided that it is big enough to show an extended image in both instruments. The scale on the hand-held camera is so small that no nebula will be seen by that camera as more than a point. When the image is smaller than the effective resolving power of the instrument, it ceases to behave as an extended image and has to be treated as a star or point image. As we saw, for a point image the crucial question is the light-gathering power of the telescope. Now for a large telescope the scale and resolution are so great that a considerable number of nebulae produce extended images. The largest and nearest nebulae are revealed in all their detailed structure: those further off are seen as mere patches of light, but as of a perceptible extension. Finally, as the limit of the light grasp of the telescope is beginning to be reached, the nebulae observed become fainter and fainter in consequence of their greater distance. The images of these extremely remote nebulae are so small that they can be treated as approximately stellar in character. For all practical purposes they remain mere points, with the result that the chief advantage of the large telescope for the observation of objects of this type is the same as its advantage in the observation of faint stars, namely, that it possesses a very great light-collecting power.

The particular problems which large telescopes can solve in the field of nebular research are numerous, and some of them, the problems of the internal structure and motion of the nearer nebulae, have already been mentioned. Further problems, selected almost at random, include the following. In studies of the star population in the neighbourhood of the sun it has been found that there is a definite relation between the colour of a star and its real absolute brightness. This relation is not simple; the observed facts are that, for example, a yellow star is either of the same real brightness as the sun or about 100 times as bright: a red star is either 10 to 100 times fainter than the sun or in the region of 500 times as bright as the sun. The best way of representing the totality of known facts is by means of the classical Hertzsprung-Russell diagram, in which data for all known stars are plotted on a diagram of real brightness against spectral type or colour. The known stars in the neighbourhood of the sun lie along a band on the diagram with a subsidiary band joining it. Evidence is now accumulating which may suggest that this type of distribution is not typical of all stars everywhere, but that it is in some way characteristic of the kind of star population which is to be found at the edges of nebulae —the sun is, of course, at the edge of our galaxy, the nebula to which it belongs. The logical thing to do is to take a look at other nebulae and to see what the distribution of star colours against brightness may be. This is a job certainly requiring a large telescope, but even then it is not as simple as it sounds. In the first place, it is necessary to find nebulae which can be resolved into stars by the telescope available, or more exactly, to find a nebula in which *some* individual stars can be distinguished. So far, any individual star which can be distinguished in an external galaxy is certain to be a giant of very great intrinsic brightness. The dwarf stars are too faint to be seen as individuals. This situation is in marked contrast to that obtaining for the part of space near the sun, where we have information in respect of quite a high proportion of dwarf stars. This problem is certain to have a close bearing on problems of the origin of nebulae and will only be solved with the aid of large telescopes.

A second problem is presented by almost any picture of any nebula. Usually the picture shows an oval area of luminosity looking like a plate presented face up towards the observer; that is, with the top edge in the photograph the more distant. But turn the photograph upside down and it still looks the same. The conviction that the top edge was further away is replaced by the equally strong conviction that what has now become the top edge is the more remote. A way of testing this is by trying to detect which edge of the nebula is reddened as compared with the other. Some say that the light from the more remote edge must have come through some of the dust associated with the nebular structure in getting here, so that if one edge is more reddened than the other (and extra reddening has been detected) then that edge must be the more remote; but like so many other astronomical problems this is still a matter of controversy.

These two instances are examples of typical problems on nebulae near enough to us to appear large. Objects of smaller apparent diameter are suited to studies of a more general kind. It has been found that nebulae can be classified into various types according to their shape and the degree of openness of their spiral structure, and that their intrinsic properties—real brightness, real diameter, and so forth—as distinct from their apparent brightness and diameter which also depend on the distance of the objects from us—are fairly well indicated by the type to which each nebula belongs. The classification of nebulae in this way is a necessary task to be undertaken by large telescopes. A second important line of work is the extension of the classical studies of the velocities of extra-galactic nebulae. It is now a commonplace that the nebulae are moving, and that, judged by the displacement of their spectrum lines, their velocity of recession increases with their distance from us. This relation has been established for nebulae in the northern sky, and is no doubt also true for southern nebulae, but the completion of the work in the southern sky is essential. It is impossible with any precision to measure the lag of southern astronomy behind northern, since southern astronomy will supplement northern knowledge by methods which may perhaps be more rapid than the pioneer ones worked out in the north. But a figure of possibly half a century may not be too erroneous; whether the new southern telescopes will enable the astronomers using them to make up this leeway or whether the new northern instruments will increase the lead it is hard to say. At all events, both north and south of the equator, the present-day advances in big telescope resources should soon produce a rich harvest of results.

Oliver Heaviside, 1850–1925

SIR EDWARD APPLETON, F.R.S.

On May 18 the Institution of Electrical Engineers celebrated the birth of a mathematical and scientific genius, Oliver Heaviside, who was born on May 18, 1850. Two days later our French colleagues in the world of electricity and radio paid their own tribute to Heaviside's life and work. Heaviside was, of course, an Englishman, and I don't think he ever visited France, but the spontaneous salute which French scientists paid to his memory is a striking illustration of how the work of a really great man belongs to everybody.

Now Oliver Heaviside, quite apart from his scientific work, is a subject, a subject in himself, for he was certainly a character. He lived much of his life in retirement and the last nine years of it entirely alone, fending for himself. He was odd, but he was also a most attractive person to those who knew him well. He had a special dislike for people who took themselves too seriously; and this was notably the case if such people expected him to take them as seriously as they took themselves. In certain ways he was at war with orthodox people and especially with the orthodox way of doing many things. That is what does happen, of course, to people who are both breaking new ground and who do not give simple explanations about what they are finding there. "Take it or leave it" was generally his motto—and most people, at any rate at first, 'left it'. However, some people took the trouble to 'take it', and found rich treasure therein. Heaviside had a dry, and somewhat impish, vein of humour. Someone once said to him: "I find your papers very difficult to read, Mr. Heaviside." Heaviside replied that that might well be, but they were even more difficult to write. Then there is his other famous remark that "Even Cambridge mathematicians deserve justice" . . . with its happy suggestion that any wounds he had received in the fight against orthodoxy had not really gone too deep.

Oliver Heaviside was a Londoner, born in Camden Town, the son of a wood-engraver from Stockton-on-Tees. He was related, on his mother's side, to Sir Charles Wheatstone, the pioneer of the Electric Telegraph; his elder brother, Arthur Heaviside, was an engineer in the British Post Office working at Newcastle-on-Tyne. So we can understand how Oliver got interested in the theory and practice of telegraphs. He used to do experiments, with his brother, on sending telegraph messages both ways along a wire at the same time. He was also, for four years, employed as a telegraph operator by the Great Northern Telegraph Company which operated a cable between Newcastle and Denmark. During part of this period Heaviside worked the Denmark end of this cable and learned a fair amount of Danish. He resigned from this post at the age of twenty-four, saying, boldly, in his letter of resignation: "I've obtained a situation elsewhere."

Heaviside must have been almost entirely self-taught in higher mathematics for he attended no technical college or university. And yet at the age of twenty-two, in the early eighteen-seventies, he was publishing scientific papers describing his experiments and theories relating to telegraphy. He resented passionately, even in those days, any suggestion from an editor that his papers should be altered in any way. "Experience has taught me", he also wrote, "that the refusal of a paper by any journal . . . implies that the paper is usually original and good. Fact!"

Heaviside started, as we have seen, as a student of telegraphy and later became interested in telephony and radio. There are many big things he did, but I propose to mention only three, the first of which was concerned with the subject of long telephone and cable lines. It had been found in those days that the length of line over which clear speech could be sent was definitely limited. This was because notes of different pitch arrived at the end of the telephone line with different degrees of weakening. Heaviside tackled this problem entirely with pencil and paper and showed how a telephone line could be freed from distortion. Moreover he suggested practical ways of doing this.

His cure was either to put coils of wire in the telephone line at suitable intervals or to wrap iron, or some other magnetic substance, continuously round the telephone line itself. But, unfortunately, his suggestions were not considered acceptable by the British telephone authorities of the day—the date was 1893—and for some years no practical advantage came from them. The first application of his ideas was made by Professor M. I. Pupin in the United States, who, in 1899, showed practically that by inserting coils in a particular telephone line, by 'loading' it, as we say, he could multiply by five the distance over which speech could be transmitted.

The loading of telephone cables suggested by Heaviside, and tried out experimentally by Pupin, revolutionised the practice of long-distance telephony. The loading reduced the weakening of the speech along the line and also improved the articulation when received. In Britain the Post Office authorities began to experiment with loaded cables in 1901, and by the end of the first World War, the loading of our main underground cables had become standard practice. By 1913, one authority had estimated that the introduction of loading had already saved the world's telephone companies more than four million pounds.

Heaviside's suggestions were also applicable to the improvement of very long submarine cables which were used for the transmission of telegraph messages. Here the 'loading' of the cable by means of coils was not considered possible because of expected difficulties in laying and maintenance. What was required was *continuous* loading, but at first, there was no material with the required magnetic properties available. But in 1923, the discovery of a new alloy, Permalloy, which had the required properties, was announced, and in 1924 the first loaded ocean telegraph cable was laid between New York and the Azores. It gave a speed of signalling of about two thousand letters per minute while, previously, two hundred and fifty letters per minute had been the maximum performance for non-loaded long-distance submarine cables.

The second of Heaviside's achievements I select for mention was his invention of a new branch of mathematics. This advance was prompted by his interest in electrical circuits and, in its best known application, enables us to deal with complicated electrical events in a simple way. Let me give you an example. Now suppose you are listening to your wireless set and you hear a sudden signal—an atmospheric or a sending station suddenly coming on the air. What happens in all the complicated maze of circuits in your receiver? The answer is, of course, all kinds of things, all happening at once or nearly at once. You get different currents in the various circuits and different voltages on the various condensers and so on. Heaviside showed us how to calculate what happens in each limb of these complicated circuits. In fact he showed us how to predict what happens in a wireless receiver, or in any electrical circuit, when a switch is closed or when signals suddenly come on.

It was in connexion with the invention of these new mathematical methods, the operational calculus as we call it, that Heaviside came up against the orthodox mathematician.

They regarded his methods as vigorous rather than rigorous. They said, in fact: "Yes, these methods may certainly give the right results in certain cases, but there *may* be examples in which they might let you down." Heaviside, in return, thought the orthodox mathematician too cautious for words; he once wrote to a friend: "Pray don't ever call me a mathematician. I'm a physical mathematician or a mathematical physicist. I repudiate all mathematicians."

However, in more recent years, the mathematicians have made ample amends. They have put his work in a formal and rigorous dress, so that it is now quite respectable mathematically. Still more recently, they've given it an entirely new dress so that, if you knew it only in its original form, you would hardly recognise it now. But the fact that it all started with Heaviside is always accepted.

The third feature of Heaviside's work I want to mention is his famous suggestion concerning the existence of a conducting layer in the upper atmosphere—now known as the Heaviside Layer, which reflects radio waves and so helps us to send radio messages all round the world.

Although Heaviside himself did experiments in electrical telegraphy he never worked at practical radio, but he thought a good deal about theoretical radio and especially about the way radio waves travel. In 1902, that is a year after Marconi had spanned the Atlantic by wireless, Heaviside was writing an article for the tenth edition of the *Encyclopaedia Britannica*. His subject was "The Theory of Electric Telegraphy," and he had occasion to compare the two processes of the travel of radio waves on wires and along the surface of the earth. It was when dealing with the latter that he suddenly wrote these words: "There is another consideration. There may possibly be a sufficiently conducting layer in the upper air. If so, the waves will, so to speak, catch on to it, more or less. Then the guidance will be by the sea on one side and the upper layer on the other."

Heaviside published nothing further on the subject and we must think of this suggestion as prompted by his physical intuition rather than as a result of long calculations. It was a bold hypothesis, and we now know that there is a Heaviside reflecting layer in the upper atmosphere; experiments have proved its existence. In fact there are a number of layers, and we nowadays call the whole group of layers the Ionosphere. I have worked at the subject of the ionosphere now for over twenty-five years and feel I have good reason to be grateful to Heaviside and others for giving me such a fascinating topic for research.

The world of science was certainly slow in recognising the genius of Oliver Heaviside. Perhaps that may have been partly due to the fact that, for the greater part of his days, he lived the remote life of a hermit, first at Newton Abbot and later at Torquay. The number of scientific people who met him was small, but I think it was larger than is popularly supposed. Letters from about a hundred of his correspondents are preserved at the Institution of Electrical Engineers. Also he took a great interest in people, and had quite a picture gallery of scientists stuck on the walls of his study. Much of our information concerning Heaviside as a man has come to us from Dr. G. F. C. Searle of Cambridge who, with Mrs. Searle, paid Heaviside nearly a hundred visits between 1892 and 1895, the year when Heaviside died. The closeness of the friendship may be measured by the fact that the last letter Heaviside ever wrote was to Mrs. Searle.

Although Heaviside's main work had been done by the time he was thirty-seven years of age, recognition of his pioneer quality came, as I have said, rather late. He was, however, elected to the Royal Society at the age of forty-one, while the State recognised his services by a Civil List Pension. He was also made an Honorary Doctor of Göttingen University. But I like best to think of Heaviside as the first recipient of the Faraday Medal of the Institution of Electrical Engineers which he received only three years before he died. Heaviside was by that time past attending at the Institution in person for the medal. And it fell to the reigning President, the late Mr. J. S. Highfield, to go down to Torquay to present the Medal personally to Heaviside. Heaviside did not hold much with honours. "I think honours have been very much overdone;" he once wrote, "the more honours the less value." But on this occasion the old man melted in the genial presence of Mr. Highfield.

It is true that, at first, when he saw the medal he criticised the wasteful expense of the beautiful leather-bound document which accompanied it. And he said he was glad the medal was made of bronze and not of gold. But then he read every word of both document and medal and was especially delighted to see the signature of an old friend on the former. As Mr. Highfield further relates in his own delightful account of this unique occasion: "Heaviside talked much about telephony and wireless, all interspersed with homely grumbles at the many defects of his neighbours. He seemed to know all that went on in the town. It's impossible to give any adequate account of one who so despises what most men admire. But," Mr. Highfield goes on, "when I left him I felt that he was content, that he respected the Institution, and that it had pleased and made happy one of its famous men."

This article is based on a B.B.C. Science Survey talk.

FIG. 2.—A takahea approaching a nest along a snowgrass runway. The bony frontal shield can be well seen.

FIG. 1.—This photograph clearly shows the bird's characteristic gait. Tussocks of *Danthonia*, the main food material, can be seen in the background.

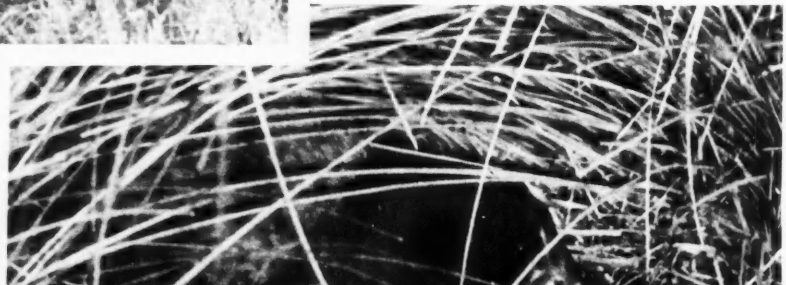


FIG. 3.—A typical nest set among the snow tussocks. There are usually two entrances.

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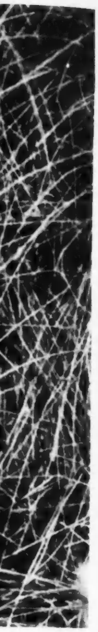

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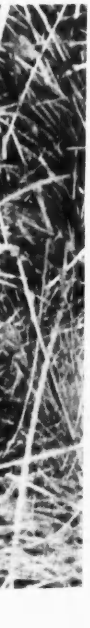


An Almost Extinct Bird

G. R. WILLIAMS

(Biologist of the N.Z. Wildlife Service)

"THE amount of interest which attaches to the present remarkable bird is perhaps greater than that which pertains to any other with which I am acquainted." So commented John Gould on the occasion when the news of the finding of the first live specimen of the *Notornis* was communicated to the Zoological Society in London in November 1850. Now, almost a century later, these words have again become as apt as they were originally, for the recent rediscovery of this bird—in the summer of 1948—aroused world-wide attention. Before discussing the natural history of this remarkable bird it may be helpful to give a brief account of New Zealand's ornithological history.

The country has not been a fortunate one so far as its animals are concerned. The result of settlement has been the extinction or near-extinction of many native species, and the introduction of others that, only too often, have become serious pests. Until the arrival of Captain Cook in 1769, the dominant class of land vertebrates was that of the birds, the only land mammals known being two species of bat, a dog and the Polynesian rat (*Mus exulans*)—the last two being introduced by the Maori on their second migration to these islands in about A.D. 1150. Consequently the vegetation of New Zealand had never been subjected to the activities of browsing animals—unless we except the various species of moa—nor had the fauna to contend with any mammalian predators. Under these rather remarkable conditions many unusual forms of life were able to survive and, as is well known, birds of little or no powers of flight were common.

The coming of the Maori hastened the extinction of the moa; but when Europeans settled in New Zealand a more extensive change began. Cook had introduced pigs, goats, black rats and domestic fowls, and within a century of his first visit such creatures as deer, cats and Australian opossums had begun to exert their influence. The forest, dominating the country except in the east of the South Island, began to shrink and its composition was altered by Man and the herbivores he brought with him. In the decade between 1880 and 1890, stoats, ferrets and weasels were introduced in large numbers to control the rabbits, and the fate of many of the now rare native birds was virtually sealed.

Among these birds was the *Notornis* or takahea. Between August 1898 and November 1948 no specimen of *Notornis* was found. In this period the bird was assumed to have disappeared completely.

The previous history of *Notornis* had been interesting. It was known to the Maori in both Islands, but in the North it had been extinct long enough to be represented only by semi-fossil remains. In the South Island, according to Maori tradition, it was once plentiful in certain areas particularly around the shores of Lakes Te Anau and Manapouri—two large glacial lakes in the mountainous and heavily forested Fiordland National Park. Annual expeditions used to be organised to capture these birds for food when the winter snows drove them down from the mountains.

The Europeans' first contact with the bird in any form was in 1847 when Mantell discovered semi-fossil remains in Taranaki in the North Island. The name *Notornis mantelli* was given to these by Owen in 1848. The first live takahea was taken in 1849 and eaten by a party of sealers on Resolution Island in Dusky Sound at the south-west extremity of the South Island. Two years later another bird was caught on Secretary Island in Thomson Sound about 40 miles further north. Mantell was fortunate enough to obtain the skins of both these birds and they were sent to the Natural History Museum in London. For 28 years no more specimens were reported and then, in 1879, a solitary specimen was killed 9 miles south-east of Lake Te Anau; after this had been studied in New Zealand by Buller and Parker, its remains were sold to the Dresden Museum for £105. Meyer decided, after examining the skeleton, that sufficient differences existed between it and the original North Island form to justify the creation of a new species which he called *Notornis hochstetteri*. However, there are good reasons for doubting his justification for this. More South Island skeletons were found in 1884 and 1892; and then in 1898 the fourth live takahea—a young female—was caught by a dog on the shore of the Middle Fiord of Lake Te Anau. The finder, realising the importance of his discovery, sent the entire bird to the Otago Museum, where it was dissected and the viscera, skin and bones preserved. The mounted skin, still kept in that museum was bought by the New Zealand Government for £250 and is the only one at present in this country.

Fifty years now passed without news of the *Notornis* except for occasional reports (generally discounted out-of-hand) of its being seen in various parts of Fiordland. It is surprising that no expedition went out to search for the bird in the locality where the last one was found. This would surely have resulted in the discovery of the present colony.

It was not until April 1948 that Dr. G. B. Orbell made an expedition into an old glacial valley on the western shore of Lake Te Anau in search of the bird. He was unsuccessful, beyond finding some inconclusive footprints and hearing an unusual bird call. Seven months later he revisited the same place. This time he was rewarded; the news of the discovery of *Notornis* was announced on the following day—November 21. It is interesting to reflect that he might have been anticipated in this discovery by more than sixty years, for, according to Herries Beattie, two explorers, McKinnon and Henry, reached the entrance to the valley but returned without examining it. Further, Beattie gives the traditional Maori name of this valley as 'Kohaka-takahea'—the nesting place, which is literally true today and has probably been true for a great many years. Dr. Orbell's find has been shown by subsequent expeditions to be a small colony of *Notornis hochstetteri*, numbering (in the author's opinion) about twenty birds, though higher estimates of the population have been given.

Since 1948 five more expeditions have been made under the aegis of the Department of Internal Affairs to the area which now forms part of a prohibited zone of almost seven hundred square miles created for the preservation of the

birds. All persons have been excluded from this area, except accredited scientists and naturalists who have now collected a great many details about the life history of *Notornis*.

It has become evident that the original range of the takahea was much wider than it is now. Fossil and semi-fossil remains have been found in the southern part of the North Island and in the north-east, south-east, and south of the South Island—all these localities, it is interesting to note, being in low country. Its present habitat, as far as is known, is in the Murchison Range area on the western shore of Lake Te Anau. The main colony is located in two parallel hanging valleys, one of which is at an altitude of 3000 ft.; the other, immediately to the south, being 500 ft. lower. The *Notornis* also occupies, for at least part of the time, the forest-fringed open tops above these valleys, and thus is found as high as 4000 ft. above sea-level and there are indications that the birds even breed at this altitude.

The Takahe Valley (as it is now commonly called) is some two or three miles in length, and about a quarter of a mile in extreme width. Occupying much of its floor is a moraine lake about 1200 yds. long by 250 yds. wide. Except at its western end this lake is fringed on all sides by short and well-drained slopes of tall snowgrass tussock (*Danthonia flavescens*) which give way first to a narrow scrub-belt of turpentine shrub (*Dracophyllum uniflorum*), *Coprosma rigida* and *Hebe buxifolia*; and then to an alpine beech forest association—mainly mountain beech (*Nothofagus cliffortioides*)—on the steep valley walls. To the west the lake is succeeded by boggy ground; and the narrowing valley floor, still snowgrass-covered, then extends for about two miles until it ends in high scree slopes under snow-clad peaks of the Murchison Range. The other valley is similar except that it is lower, less open, has no large lake and shows signs of being sometimes subject to flooding.

For about eight months of the year the main area is virtually free of snow. During winter and early spring snow covers the Takahe Valley floor to a depth of 2 ft. or more and the lake freezes over. Winter or summer, as has already been pointed out by Dr. R. Falla, food for most birds is rather scarce.

During the warmer months the takahea range freely through the forest and snowgrass flats in the two valleys, covering considerable distances within what appear to be fairly well-defined feeding ranges—each generally occupied by a mated pair. In winter most seem to desert the exposed valley floor, except when foraging for food, to seek shelter in the fringing forest. The takahea now range up to about a mile a day in search of food.

Feeding Habits

The diet of the *Notornis* shows some variation throughout the year. The adult bird appears to be mainly, perhaps entirely, herbivorous. The commonest food seems to be the succulent bases of the tall shoots of the snow tussocks.

There is some change of diet during the winter months when heavy snow covers the valley floor, and the birds migrate to the forest. They turn to other plant species to eke out the supply of snowgrass; mosses and the succulent parts of some shrubs appear to be eaten, and it is possible that insects are also taken at this time.

By the time they are about a month old *Notornis* chicks are able to feed themselves on a diet that seems predominantly vegetarian. At this age they have not learned the adult method of feeding but pick at tender shoots and frequently take leaf bases from the beak of the attendant bird. As well as the usual *Danthonia*, chicks are known to eat the leaves of *Viola filicaulis*—the native violet.

In its appearance the takahea bears a strong superficial resemblance to its relative the pukeko or swamp hen (*Porphyrio melanotus*)*, which is found throughout Australasia. However, it is bigger, and more sturdily built; one measured in the winter of 1949 stood about 20 in. and weighed 6 lb. It is, of course, flightless. It is well depicted by Buller in his *History of the Birds of New Zealand*, but only in the first edition is the rendering of the colour of the soft hair-like plumage accurate. Another excellent plate in colour may be found in Rothchild's *Extinct Birds*.†

Although flightless the takahea has fairly powerful wings armed with a carpal spur, and its large beak is capable of inflicting a painful wound.

In the author's opinion the *Notornis* is primarily a bird of the forest margin rather than of the open grass country. The birds seem to be most active in the early morning and evening; there is some nocturnal activity, but it is hard to say how much as it is difficult at times to distinguish their call from that of a weka (*Gallirallus australis*) or a kiwi (*Apteryx australis*), both of which are nocturnal and found in the same area. In gait and posture the *Notornis* resembles the weka; and like the pukeko it has the habit of flicking its tail from time to time. When alarmed it may break into a surprisingly fast run with head and neck lowered and often uses its wings to gain impetus; it has a stride of from 12 to 15 in. and covers most kinds of terrain with ease. Water is not necessarily avoided and the bird is able to swim. However, boggy ground is not favoured.

Various calls are known. The usual one between members of a pair is a high pitched, yelping 'ker-lonk' uttered on a rising inflection with the second note cut short. This cry is varied occasionally to a shorter 'klowp'. The alarm note is a percussive, gulping 'boomp, boomp' which is not very loud but is highly distinctive.

One of the most notable facts about the takahea is the way in which particular pairs seem to keep within a fairly well-defined area throughout most of the year. The area occupied by the *Notornis* colony has been previously estimated at approximately 500 acres but probably little more than half of this consists of the right proportion of

* Perhaps more correctly *P. poliocephalus*.

† The following description is from field notes made during the winter expedition of 1949 in the month of August: The head, neck, breast and flanks are an iridescent indigo blue becoming brighter on the shoulders and changing to a metallic sage-green on the mantle. The back, rump and upper tail-coverts are olive-green; the abdomen, thighs and vent purplish-black; and the under tail-coverts white. A striking contrast is provided by beak and legs—the former being scarlet at the base and fading outwards to a rose-pink, and the latter bright red. (There is no obvious sex-difference in the plumage or other coloured parts). This brilliant colour scheme is seen to full advantage only when the bird is approaching or passing at right-angles to the observer. From behind the colours fade into drabness. The newly hatched chick is covered with a soft black down almost furry in texture, the bill is white and the disproportionately large legs pale purple. At about a month the plumage is still much the same but the bill has become a dark steely grey except for the tip and the legs have already begun to change to the adult coloration by showing a narrow anterior, vertical rust-coloured stripe.

FIG. 4.—Takahea Valley with the Murchison Range in the background. The birds feed on the snowgrass flats between the lake shore and the forest edge.

forest and grassland that the birds require. In the breeding season, when they are concentrated in the snowgrass, probably no more than about 150 acres are in general use. This area is shared by seven or eight pairs of birds and perhaps one or two non-breeders. In the 1949–50 season only one chick survived until February 1950 as far as is known, and by studying the pair 'labelled' by the presence of the young bird it was possible to compute that a feeding area of approximately 15 acres was being solely occupied by them. There is no reason to doubt that the other pairs were occupying similar sized areas at the same time.

Breeding

Indications are that the breeding season begins in October and lasts for three or four months. After building a number of nests, each of which consists of a grass bowl about 18 in. in diameter and 3 in. deep set between thick *Danthonia* tussocks, the last made is apparently chosen and either one or two eggs are laid. These are greyish-white in colour and marked with spots of brown and light purple and their dimensions are approximately 3 in. by 2 in. Incubation—the time of which is not yet known—is carried out by the smaller bird, presumably the hen, who begins to sit upon the egg or eggs within three or four days of the completion of the nest. The male is then reported to leave the vicinity. From the amount of droppings and feeding signs that are always found round about, it is obvious that the sitting bird seldom travels more than a chain from the nest. Observations over two nesting seasons indicate that most, if not all, of the birds in this area breed yearly but that very few chicks are raised—perhaps because of low egg fertility as there is little evidence of serious predation of the eggs themselves or of more than one chick being hatched from any one nest. Three chicks are known to have hatched in the 1949–50 season, but only one of these was alive at the time of the last expedition which was in February of this year.

Among the natural and potential enemies of the takahea must be included stoats, deer and falcons or bush hawks. In time, it is not unlikely that an uncontrolled influx of the Australian oppossum into the area might indirectly have an adverse effect. So far, rats have proved to be very rare, and cats are unknown. Measures have already been taken by the Wildlife Service of the Department of International Affairs to control the predators, and it is believed that the recent breeding season has been almost stoat-free. Deer, which may disturb nesting birds or tread on the nests or fledglings, have been destroyed whenever possible. It now remains to be seen what the long range effects of continued predator control will be. Other areas in the two-million-acre Fiordland National Park where the environment is likely to be such that takahea may survive are being explored from time to time, as it is considered likely that there may be other small colonies erratically distributed in this part of the country. Except in the immediate vicinity of the present colony, however, all such searches so far made have proved unsuccessful.

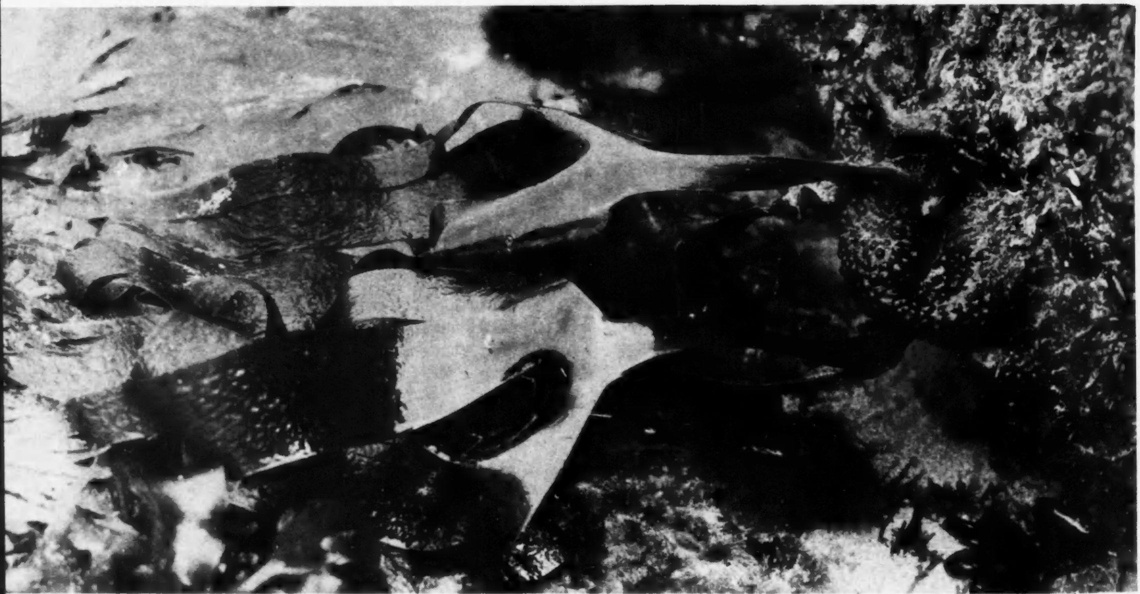
Experience may show that it will be impossible to maintain the birds indefinitely in their wild state. Nevertheless, it is hoped that study and rigid protection will do much towards ensuring that the history of so many other rare birds will not be repeated this time.

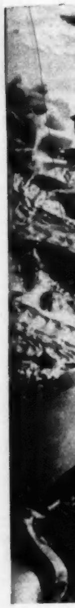
(*Photographs by H. J. Ollerenshaw*)

PHOTO-GUIDE to BRIT

(*Photographs by D. P and M. A*

Laminaria digitata. × $\frac{1}{11}$. *Tangle or oar-weed. Common at low water spring tides. Oar-weeds are harvested for the extraction of alginic acid which has many commercial uses.*



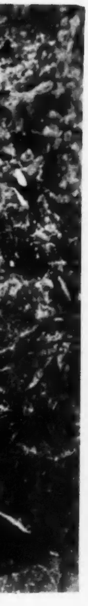


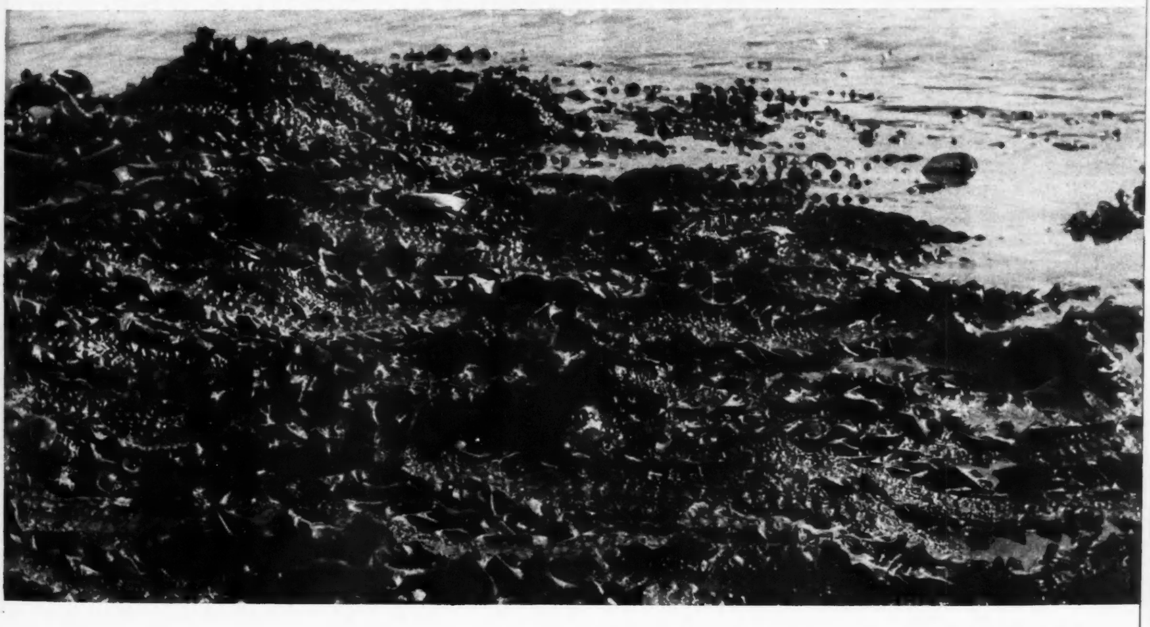
Saccorhiza bulbosa. × $\frac{1}{7}$. *Furbelows. Fairly common brown weed at low water spring tides and below. The stout stipe is flattened and becomes waved at the edge; at the base is a large hollow bulb covered with warty protuberances.*

DE to BRITISH SEAWEED

hs by D. P and M. A. WILSON)

Laminaria ochroleuca. $\times \frac{1}{7}$. *An oar-weed new to Britain; in the last few years it has spread from France to Plymouth, Salcombe and Helford River. Distinguished by its stiff stipe (stalk) and pale yellow frond.*

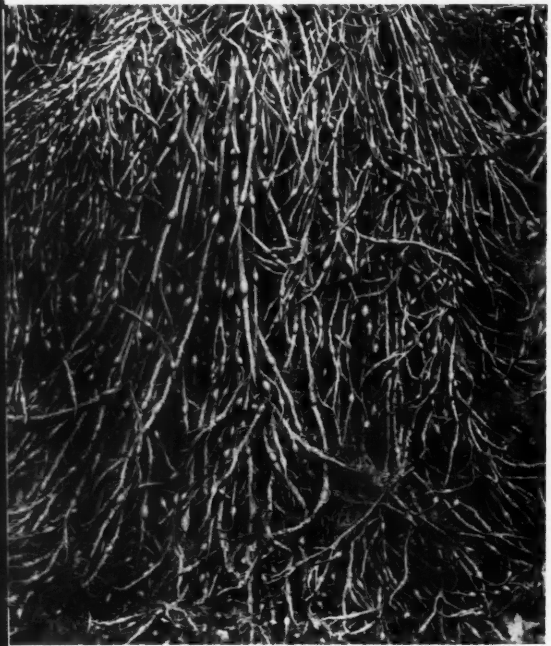




Laminaria saccharina. $\times \frac{1}{11}$. *A common oar-weed with long crimped fronds—found at low water spring tides.*

Fucus serratus. $\times \frac{1}{4}$. *Notched Wrack. Common from mid-tide downwards. The margin is serrated, there are no bladders and the fertile tips are not swollen. Useful for packing lobsters, etc., as it is not mucilaginous.*

Fucus vesiculosus. $\times \frac{1}{4}$. *Bladderwrack. A common brown weed found at the same shore level as* Ascophyllum. *Note the paired bladders. The swollen forked tips contain reproductive organs.*



Ascophyllum nodosum. $\times \frac{1}{8}$. *Knotted Wrack. Common on fairly sheltered shores. The tough elastic fronds may be 6 feet long and are buoyed up by stout-walled bladders.*

Pelvetia canaliculata. $\times \frac{1}{3}$. *Channelled Wrack. Brown weed common above high water neap tides. Bright yellow fertile tips in late summer. In some parts sheep eat it.*

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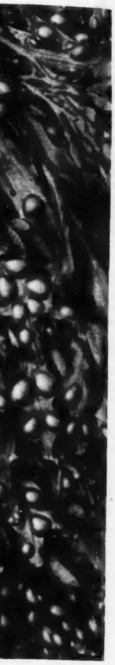

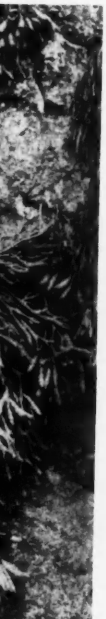

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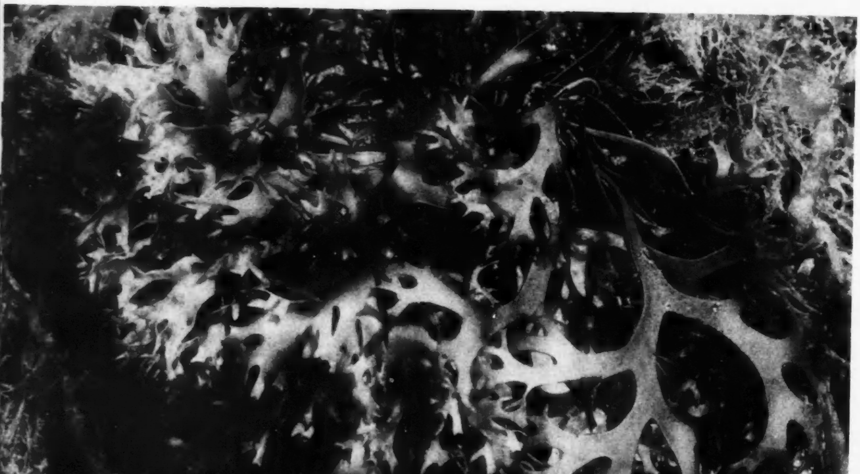
Himanthalia lorea. × ⅔. *Thong-weed. Brown weed not uncommon just above zone of oar-weeds. Starts as a small sphere which flattens to a stalked button; in the second year branched thongs up to 6 feet long grow out.*

Leathesia difformis. × 1. *Brown weed common in summer on rocks and weeds. The spherical or irregularly lobed fronds are hollow.*

Polysiphonia fastigiata. × ¼. *Tufts of this dark red filamentous weed are almost always found on the Knotted Wrack* (Ascophyllum). *Many small animals live in the tufts.*

Scytosiphon lomentarius. × ½. *Common on all shores, in mid-tide region, in summer. Greenish-brown tubular fronds constricted at intervals.*



Chondrus cripus. $\times \frac{3}{8}$. *Irish Moss or Carragheen. Red weed common on all shores, on rocks and in pools. Varies from dark red to yellow-green in full sun. A jelly can be obtained by boiling it with water or milk. The allied* Gigartina stellata *is collected in Scotland for the manufacture of agar.*

Padina pavonia. $\times \frac{1}{3}$. *Peacock's tail. Brown alga widely distributed in warmer waters. Locally abundant on Channel coast in shallow sandy pools in full sun. The fan-shaped fronds carry long red-brown hairs and show concentric whitish markings and some iridescence.*

Bifurcaria tuberculata. $\times \frac{1}{3}$. *Allied to the wracks but with smooth cylindric branches. Not uncommon in pools mid-tide region in south and west; here shown in unusual position on reef uncovered by lowest spring tides.*

$\times \frac{5}{8}$. *Irish Moss*
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Corallina officinalis. $\times \frac{1}{2}$. *Jointed Coralline. Common in pools and on rocks mid-tide level to below low water. Purple-pink to whitish-yellow, according to exposure to sun; the branches are stiffened by an impregnation of lime. Formerly used as a vermifuge.*

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Chorda filum. $\times \frac{1}{10}$. *Sea-bootlaces. Common in summer in deep pools and below low water. Brown cylindric fronds covered with long slippery hairs. May reach 12 or more feet long and be a hindrance to boats and swimmers.*

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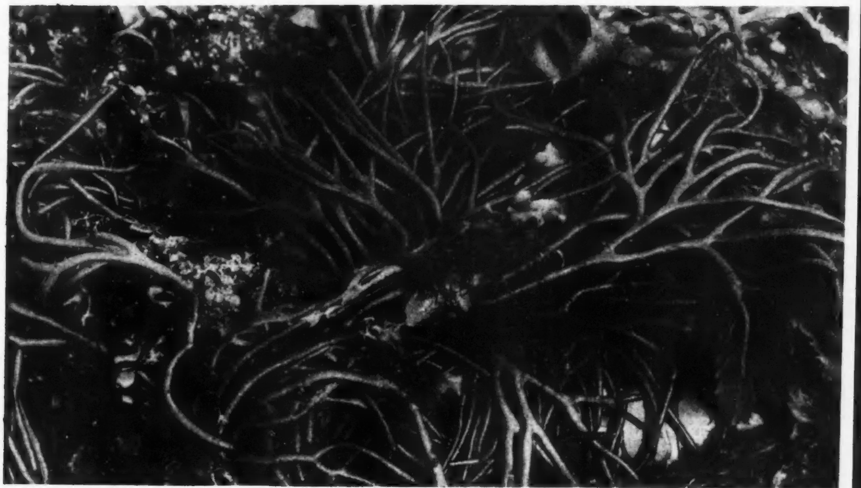

Codium tomentosum. $\times \frac{1}{3}$. *A dark green weed with cylindric forked branches and a spongy texture. Scattered plants not uncommon in deep pools and near low water.*

Commander Ian Cox is the Science Director for the Festival of Britain. In this article he describes the scope of the activities and exhibitions in which science will be on display in 1951.

Science in the Festival of Britain

IAN COX, M.A.

THAT science is international is the generally held belief in Britain. To this international store of knowledge and experience, however, Britain has contributed at least as much as any other country; it is natural, therefore, that science will occupy a proud and exciting place in the Festival of Britain in 1951, when the whole of the country will be 'on show'—not only to visitors from abroad but to its own people—proclaiming what has been achieved here in the past, what proceeds now and what is planned for the future.

The opportunities for the display of science during the summer of 1951 are twofold. On the one hand, it forms a very important element in a number of officially organised exhibitions which are the responsibility of the Festival of Britain Office, a Government Department brought into being specially for the purpose. In addition to this it will be the subject of special sessions, and conferences arranged by the learned institutions and societies. It is possible already to instance some examples of these. In Edinburgh the British Association meeting will be specially planned to make a full contribution to the Festival. In London, the Royal Society of Medicine—the leading scientific medical society of the British Commonwealth with an international membership—is arranging a number of meetings at which men and women who have contributed notably to the recent advance of medicine in Britain will themselves give an account of their work. These will take place at intervals from May until the beginning of July.

The Institutions of Naval Architects and Marine Engineers are inviting experts from all parts of the world to a ten-day conference which will meet successively in London, Glasgow and Newcastle. Similarly, the Institutions of Civil, Mechanical and Electrical Engineers are arranging a joint conference with a wide programme that will last about a fortnight in the beginning of June.

The Conference arranged by another Institution—the British Radio Engineers—extends over the whole of the Festival period. The range of subjects for discussion is a wide one and includes, for example, the specialist aspects of electronic instrumentation and of television reception and transmission. The latter will be the subject of a summer school to be held in Downing College, Cambridge. Such activities as these will be numerous and varied, and will be mainly of interest to visitors who are themselves scientists or technologists. They are, of course, essentially the concern of the learned Societies and Institutions, but the Festival Office is able to co-ordinate plans to prevent overlap in the date of these activities, and will ensure, when plans are sufficiently advanced, that a comprehensive programme is issued.

In the official exhibitions in 1951, on the other hand, science will be displayed primarily for that large section of the public which has no specialist training. Three projects in particular are designed, in whole or part, for its display. Two of them are in London—the Thames Bank Exhibition, and the Exhibition of Science in South Kensington—while in Glasgow there will be an Exhibition of Industrial Power.

The Thames Bank Exhibition is the largest ever to employ the narrative technique. It tells the story of two forces—the initiative of the People, and the resources of their Land—acting together to engender the contributions to civilisation of which the British are justly proud. It will be shown, too, that this combination is as potent and creative as ever it was, and that the future of Britain is well founded on the continuing achievements of her scientists, industrialists, technologists and designers. The story will largely be told through visual examples drawn from science and industrial design.

The Exhibition is not a trade show. No organisation, whether commercial or otherwise, has been allocated space in which to mount its own displays. There will, of course, be many industrial products on view, but these will have been selected as illustrative of the theme, and for the excellence of their design.

The stress will be on the present, and on the applications of its subject matter to the improvement of the human lot. The background against which the industrial and scientific displays will be shown is the living, working world today, a particular aspect of which gives the title to each pavilion —'The Country', 'Natural Resources', 'Power and Production', 'Sea and Ships', 'Homes', 'Sport', 'Health' and so on. Thus, there will not be sections devoted to any one science or industry as such; achievements in each will be displayed in a number of different settings as relevant to the story.

The Dome of Discovery

A feature that has already excited attention is the great Dome of Discovery. Whereas the other sections in the Exhibition will be mainly concerned with achievements visible in Britain, in the Dome the scope of display will not even be limited by the boundaries of the earth itself. While science will be shown in its particular applications in other sections, it is the Dome that offers it special opportunities for display on its own ground. The subject matter here will range from British discoveries in the depths of the oceans and the deepest underground, over the land, through the atmosphere and the ionosphere, and away in outer space itself. Proper attention, too, will be given to those other British discoverers who have looked, as it were, inwards, gradually revealing between them the secrets of the architecture and behaviour of matter and ultimately making possible such achievements as electric power, television, synthetic drugs, plastics, steam power or the many results of nuclear fission.

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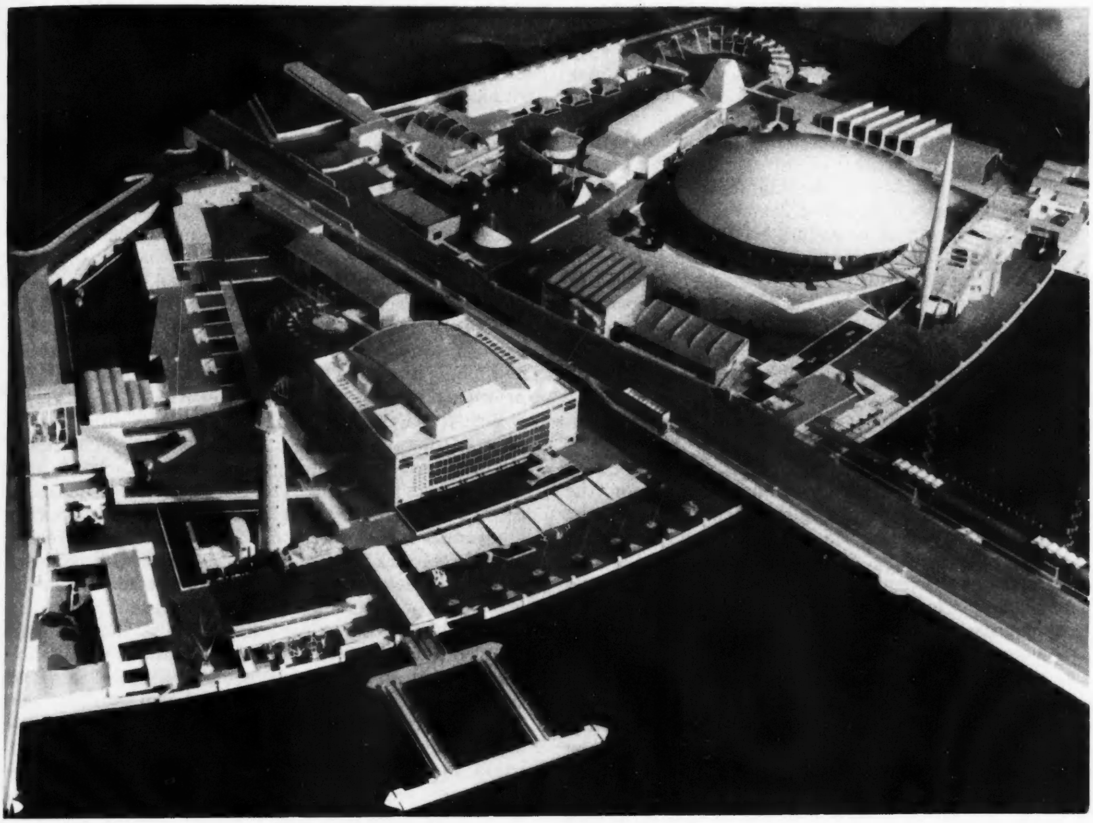
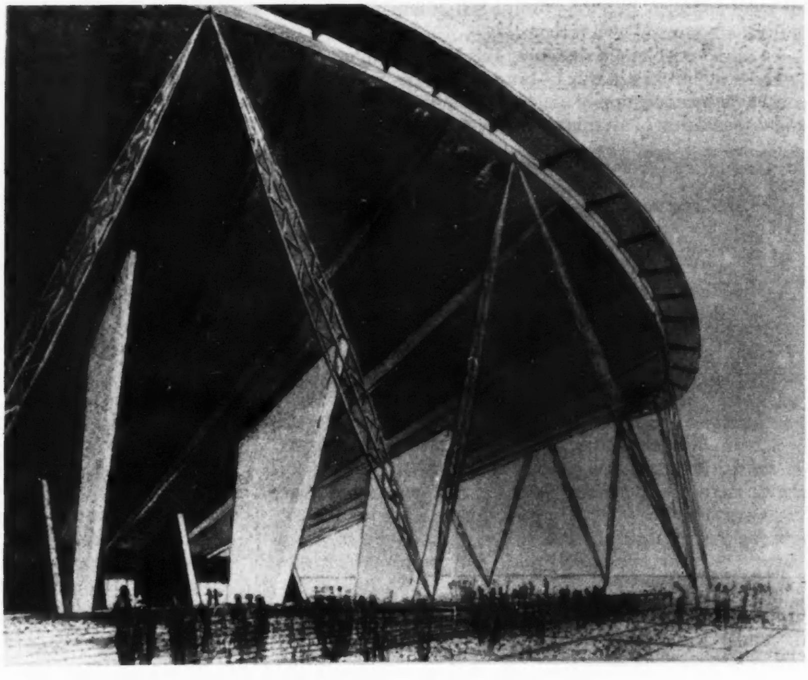


The model of the Festival buildings on the South Bank. On the left of the concert hall is the Shot Tower and on the far side of Charing Cross railway bridge is the Dome of Discovery with the vertical feature in front.



(*Right*) What the entrance to the Dome will look like.

Such discoveries in the past, however, will be displayed in the Dome only in so far as they have laid the foundations of our present state of knowledge or contributed materially to it. The basic theme of the Dome is that British initiative in discovery and exploration continues with all its old force, and with increasingly more effective tools and methods which are being provided by the explorers in the so-called pure fields of research—the physicists and chemists and so on.

One example of new techniques being brought to bear on old problems is the Radio Telescope which will certainly be a great public attraction. By means of this instrument visitors in the Dome will be able to see, and perhaps hear, radio waves from the sun, stars and even from meteors, and themselves to transmit radio signals to the moon, and observe their reflection back to the earth again after a few seconds.

Exhibits at South Kensington

In the Exhibition of Science in South Kensington, the main emphasis will be on the spirit of scientific discovery, which has always flourished in Britain, and on recent advances in unravelling the structure of matter, and in explaining the mechanism of life itself. This Exhibition is not being designed for men of science or professional technologists, although they will undoubtedly find many new methods of presentation to interest them. Its target audience is that growing section of the general public with no specific scientific training, but nevertheless an active curiosity about scientific affairs. It will be housed in the ground floor and basement of what will eventually be the new wing of the Science Museum. The Ministry of Works is speeding up construction to provide the shell structure on which Mr. Brian Peake, the architect, is working to provide the most appropriate setting for the Exhibition. Plans and designs are already well forward.

An initial problem in designing this Exhibition has been to find an appropriate way of introducing the visitor to an entirely new conception of scale that permits understanding and visualisation of atomic and nuclear structure. To solve this, entry to the Exhibition has been designed to pass through a series of chambers in which an ordinary object is successively magnified until the spectator, his vision narrowed to the detail of a single crystal, can see the atoms which compose it. Like Alice, nibbling her magic toadstool, he will seem to become increasingly smaller and finally, when the crystal is magnified ten thousand million times, to wander through a wonderland in which the nucleus of the atom and its surrounding electrons are spread all around him.

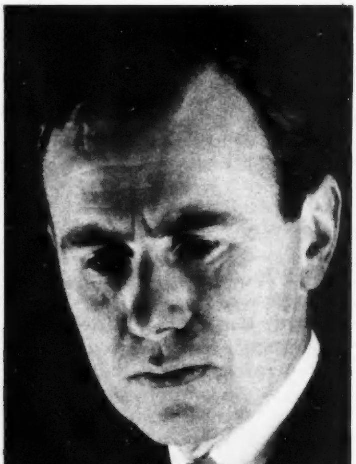
If, like Alice, the visitor is given to asking questions he may well wonder how the atoms, through which he has just wandered, and which are seen to consist largely of empty space, square with a world of shapes, colours, scents and life. The display in the main body of the Exhibition provides him with the answer.

Firstly, new working models of the apparatus used by Sir J. J. Thomson, Lord Rutherford and others in exploring the atom will demonstrate how man can come to grips with particles so minute. These displays will culminate on the one hand in an exhibit devoted to the splitting of the atom and peaceful applications of atomic energy, and on the other in a series of moving models of the different sorts of atom, which in combination give rise to the familiar materials of which things are made.

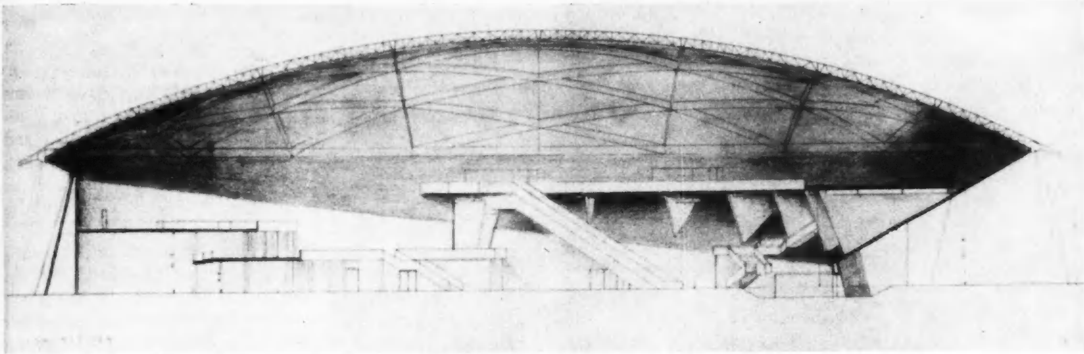
It will be shown that, according to the manner of linkage between different atoms, three broad groups of materials are formed: minerals, metals, and so-called 'organic' compounds forming the substance of plants and animals. The complex structure of the molecules of such organic compounds as sugars, fats and proteins will be demonstrated, and then it will be shown how these materials are built into living cells. Models and photographs will illustrate the aggregation of cells into complete living organisms. Some of the questions that the biological exhibits will answer are: How do plants and animals reproduce? Why does a cucumber, for example, grow in its own typical shape and colour and not like a tomato? How do the parts of a complicated organism like man work together in an harmonious way?

Ian Cox, Director of Science to the Festival.

Ralph Tubbs, architect of the Dome of Discovery.



Brian Peake, chief architect and designer of the Science Exhibition.



Sectional drawing of the Dome of Discovery. The diameter of the aluminium dome itself is 365 ft., and the apex is 93 ft. from the ground. The only support to the dome is given by light tubular steel struts. There are to be three galleries at different levels inside the dome from which a panoramic view of the exhibits will be obtained. At the centre of the drawing can be seen the moving staircase which will lead to the highest gallery. This gallery is supported by concrete buttresses.

In the final section the very latest results of current research will be shown. The displays include four main groups which at this stage in the planning may be described as (i) 'How We Know'—showing how man himself is the ultimate instrument of scientific observation and what this implies; (ii) 'The Solid State'—displaying some of the recent advances in knowledge of metal physics and associated properties of matter such as semi-conductors and low temperature behaviour; (iii) 'The Problem of Life'—presenting the physical, physiochemical and biophysical knowledge of life processes, and (iv) 'The Origin of Matter'—another rapidly advancing frontier of science with excellent visual material ranging from geochemistry to cosmic radiation and astronomy.

The Science Exhibition at South Kensington will *not* be arranged in conventional museum fashion, with small specimens laid out on benches and in glass cases. Written explanations will be cut to a minimum, and the demonstrations will be visual. Every device of show technique has been considered. Motion pictures, animated diagrams, stereoscopic photographs, electric signs, moving three-dimensional models, as well as actual examples of historical apparatus, will all be used. The atomic models are being specially designed for the exhibition with the collaboration of leading experts in wave mechanics, and will employ cathode ray tubes similar to those used in television screens. A cinema for the showing of some of the best short scientific films made recently in Britain will be another feature.

The preparation of a science exhibition along such novel lines is in the hands of a small central staff of highly trained scientists, working in collaboration with artists and specialists from the entertainments industry. Beyond this compact organisation, and standing for rigorously accurate presentation, are the celebrated scientists, the learned institutions, and trade research associations and manufacturers from all over Britain, who are giving voluntary and willing help in making the South Kensington Exhibition a worthy tribute to British science.

The Exhibition of Industrial Power in Glasgow is being designed to display outstanding British achievements in heavy engineering and its associated technologies. Like the two Exhibitions in London it will have a narrative form, the exhibits being arranged round the central story of British contributions to the conquest of power. The Exhibition develops two sequences based on the two main sources of power in Britain—Coal and Water. The Architect and Chief Designer is Mr. Basil Spence.

Implicit in the story is Britain's rise as an industrial country; the time setting, however, will be the present, and topical subjects, including the part now played by the research scientist, will be given pride of place. The north of Scotland Hydro-Electric Scheme will form an important display. Topical subject matter will also be provided from abroad by the Nile Valley Irrigation Scheme, where British engineers have helped to improve the standard of living of millions of people.

The display space in all of the exhibitions is far too limited to permit a comprehensive demonstration of the achievements in any one science. Selection of topics for display, therefore, must of necessity be very severe. In the first place it started with limiting and defining the scope of the Exhibitions themselves.

The body specially called into being for advice on such policy is the Council for Science and Technology, of which Sir Alan Barlow is Chairman. Once such policy was formulated, however, it became necessary to exercise even further selection, for the contributions in all the main branches of science have been far too numerous to permit the display of all. For advice in this most important process specialist panels were formed—one for each main science and several others besides. The members of these panels are all leading authorities in their own subjects and serve voluntarily. The selection of subject matter, then, has been the result of a far larger concentration of expert opinion than can ever have been the case in similar circumstances previously.

The next stage has been the assessment of all proposals in terms of display possibilities, for even the most important subject matter is not suitable for inclusion in an exhibition, unless it can be demonstrated visually, and with very little explanatory wording. The factual material having all been provided by acknowledged experts, the designers, in constant collaboration with the scientific staff of the Festival Office, are now very busy converting this into the visual displays that will make the Exhibitions a reality.

WATER EROSION

This picture shows how huge quantities of soil can be swept away by rain. (*U.S. Dept. of Agriculture picture*).

Bombardment of raindrops can destroy soil structure, making the soil more erodible. This picture was taken (with $\frac{1}{25}$th second exposure) in the hydrological laboratory of the U.S. Soil Conservation Service; the rain splashes here reach a height of no less than 20 inches.

WIND EROSION

Aftermath of a series of dust storms; an abandoned farmstead in Oklahoma. (*Photo by B. C. McLean, U.S. Soil Conservation Service*).

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Soil erosion is a challenge to science. As Lord Boyd Orr has said, the advances of agricultural science are rendered useless if there is not enough good land for farming, and "if the soil is wasted by erosion then the battle to free mankind from want is certainly lost." So far science has contributed little to practical conservation measures; there is abundant scope for research here. This article by the director of the Commonwealth Bureau of Soil Science considers soil conservation in its many aspects, and considers the bearing of science on soil conservation problems.

Soil Erosion and Conservation

G. V. JACKS, M.A.

THE area of cultivated land per head of the world's population has been estimated, admittedly with the probability of a large error, at 1–2 acres. It has also been estimated that a half to two-thirds of the human race do not get enough to eat, and that world population will increase by 500,000,000, or 20%, in the next 20 years. It may be remarked that this does not seem to be an unusually rapid rate of increase; if earlier estimates of world population were no more unreliable than recent estimates it would appear as though an average increase of 1% per annum has been normal for at least the last two centuries. One estimate puts world population at 750,000,000 in 1750, and although we do not know whether two-thirds were undernourished then, it seems probable, in view of the fact that famine was a normal occurrence in many countries, that the proportion was rather higher. So in spite of trebling its population and certainly reducing the area of land per head, mankind is better fed than it was in 1750.

Hitherto, increase in food production has kept pace with increase in population mainly by extending the area of food-producing land. There is still scope for further extensions of agriculture, but not on the immense scale of the nineteenth century, and future increases must come more and more from intensifying production on already developed agricultural land. Nearly all land that is naturally fertile and readily accessible is already utilised for food production in one way or another, but nowhere has the economic productivity of land (that is, the amount it pays to produce from a unit area) approached the potential productivity (the amount it can produce regardless of cost). According to the law of diminishing returns every additional input of a particular kind of labour or capital into land will result in a smaller increase in output and, as the cost of further increases in yield rises, a time may be coming when it pays better to reclaim waste and marginal lands than to increase productivity from already relatively productive land. More attention is, however, at present being given to raising productivity than to increasing the productive area.

The reclamation of eroded land that is now being undertaken on an extending scale in many countries is an example both of the enhancement of the productivity of already productive land (where soil erosion is not far advanced) and the restoration to productivity of land which is so badly eroded that it has become useless to agriculture. A vast area of land has suffered more or less severely from soil erosion in the last hundred years. It is impossible to make any estimate of the total area involved, but it must run into millions of square miles. Most of this area, however, is still productive, though less so than it was; much of it would be classed as 'marginal' land that can scarcely pay for its cultivation, and some of it ought never to have been cultivated. Where soil erosion has not advanced so far as to be irreparable the power of the land to recuperate is often remarkable. The American Dust Bowl, which came into being in the 1930s as a result of a series of drought years when crops failed and the topsoil was blown away from millions of acres, has shown a dramatic recovery in recent years in which rainfall has been greater than average; grain yields have been among the highest ever recorded. The once widely held belief that soil formation cannot be accelerated beyond the slow rate at which Nature works has been discarded. Under favourable circumstances, provided the raw inorganic materials—weathered rock, plant nutrients and water—are available, the necessary organic materials—living organisms—can be multiplied, and the interaction of the two will give quite a productive soil in a few years. The rebuilding of eroded soil is a biological process of considerable complexity, but one which, to an increasing extent, is coming under man's direct control.

It cannot be said that the destruction of fertile topsoil by erosion, vast as the extent of it is, is a direct factor of any great significance in the race between population and food supply when it is considered in terms of the world as a whole. Soil erosion may be regarded as a symptom of a misuse of the land that might have had very serious consequences had attention not been drawn to it by this very dramatic symptom. For the occurrence of soil erosion is an almost infallible indication that the fertility of the land is falling.

The gradual realisation, which since the first World War has spread over most of the world, that soil fertility is nearly everywhere running down is producing a revolution in agricultural systems from soil exploitation to soil conservation. It is a beneficent revolution that will take some centuries to complete itself, but it has already progressed far enough for us to see the shape it is taking.

It is not always recognised that a mass of small rock particles, of which most soils are composed, is a very unstable deposit which will not stay in place on even a gentle slope or on a flat surface exposed to wind. There are two main reasons why soils normally do not erode. One is the cover of vegetation that protects them against the direct impact of rain and wind, and the other is the physical properties which a mass of rock particles acquires when it becomes a soil, which makes a soil resistant to erosion, and which are most strongly developed in a fertile soil. Soil erosion of farmland is liable to occur because the protection given to the soil by agricultural crops is not as great as that given by natural, perennial vegetation, and because, unless

fertility is maintained at a very high level, the physical condition of the soil may deteriorate to such an extent that the soil becomes incapable of withstanding the natural forces of erosion. It is the high fertility of British soils, quite as much as the mildness of the climate, that makes soil erosion a negligible factor in Britain. Erosion has been most severe on land of low fertility, although large areas of once highly fertile soils—for example, the black earths of North America and Russia—have also suffered serious damage as a result of their fertility being depleted by cropping.

The best, indeed the only permanent, way to prevent soil erosion on agricultural land is to build up soil fertility and, with it, the physical structure that enables soil to resist erosion. The chief scientific contribution to solving the problems set by soil erosion lies in the scientists' explanation of the common-sense measures of soil conservation devised and found effective by ordinary farmers, foresters and other users of the land. The scientist can now give a physical, albeit rather crude, definition of soil fertility, and he has shown that the physical properties of a fertile soil are those which will also protect a soil from erosion. He can give information, based on established scientific principles, on what systems of land utilisation will produce an erosion-resistant soil, though the hardest task of all—the task of creating political and economic conditions in which those systems will work—is outside the scientist's scope.

The scientist's main contribution to soil conservation has been to elucidate the nature of soil structure. The only structure of any value in agriculture is 'crumb' structure in which the soil particles are aggregated into hard porous crumbs that are obvious to everybody who has handled a soil in good tilth. All the physical, chemical and biological properties of a soil influence the development of its structure, and to produce a favourable structure in a structureless soil involves very delicate adjustment of the factors of soil formation.

The physical fraction of the soil that is most active in structure formation is the colloidal fraction composed of clay and humus. For structure formation the colloids must be flocculated, but still sufficiently dispersed to act as a cement to bind the separate soil particles into aggregates. For this the soil—at least in temperate climates—needs to have a reaction in the neighbourhood of pH 6–8 and to be well supplied with lime. The clay and humus must be very intimately associated—possibly chemically combined —and it seems as if this will not happen to an appreciable extent in the absence of an active soil fauna. Some animals —notably, but not exclusively, earthworms—are very active in this respect, others are useless. But the most important agent in forming soil crumbs are the roots of plants, and particularly the grasses.

The roots in a well established turf or pasture are so numerous that they are seldom more than a fifth of an inch apart. Each living root withdraws water from the soil in contact with it, and as water is removed the fragment of soil between the roots shrinks and separates from the rest of the soil as an aggregate or crumb. The crumbs are highly compressed by powerful capillary forces acting on their interiors where reducing conditions obtain, while on their exteriors oxidising conditions obtain. An important result of this is that soluble substances are formed in the interior of a crumb and move towards the exterior where they are oxidised and deposited as a kind of protective cement which prevents the crumb from disintegrating when wetted. Crumbs can also be created in soil by appropriate cultivation and manuring, but such crumbs are not water-stable as are those made by grass roots, have only an ephemeral existence and are of little value in preventing soil erosion.

In a soil with a grass-made structure all the soil colloids are aggregated into crumbs. The colloids are the more active soil constituents producing fertility, but they can be more of a nuisance than a blessing when they are unaggregated. A soil with a grass-made structure has also two sharply defined types of pore: capillary pores inside the crumbs where water can be stored even in times of prolonged drought, and non-capillary pores between the crumbs from which excess of water will drain and into which air will enter. Such a soil is thus equipped as well as can be to provide plants with water and air in suitable proportions under all weather conditions; it provides the best growing conditions for most crops, and also maximum resistance to erosion. Thus we see how the study of soil structure, which has always had great theoretical interest, is becoming of profound practical significance.

Soil conservation in its narrower sense of preventing soil erosion or in its wider sense of maintaining agricultural soil fertility is thus essentially a matter of making and preserving crumb structure. It can be quite a simple matter; it can be extremely difficult. In regions where the physical conditions are unfavourable to plant growth it is most difficult because soil fertility and soil structure are creations of living plants. A whole complex of special measures, adding up to a complete and more or less rigid agricultural system, may then be necessary, firstly in order to hold mechanically the impoverished, erodible soil in place until, secondly, fertility and erosion resistance can be built up by appropriate cropping practices so that the soil will stay in place without mechanical aids.

The oldest and still the most widely used method of mechanically holding soil in place is by building terraces, ridges or other constructions which have the effect of flattening out a slope or breaking up a long slope into a series of shorter slopes. The control of water erosion is largely a matter of stopping water from running downhill, and a terrace does this by removing the hill. The same effect is produced by 'contour cultivation' which means performing all cultural operations like ploughing along natural contours across slopes instead of, as is done in this country, up and down slopes. Each furrow formed by the plough then acts as a level ditch in which run-off water is caught and held until it can be absorbed by the soil. Contour cultivation is also valuable as a means of snow retention which is especially important in continental regions with a cold winter and a hot, dry summer where most of the annual precipitation occurs as snow which, if it is not wholly absorbed by the soil in the few days of the spring thaw, is lost irreparably to the following crop.

Terracing and contour farming, however, valuable as they are as palliatives against erosion, do nothing to build up fertility and erosion resistance in the soil. To achieve this it is necessary to discover, for each particular environment, the cropping system that will provide the maximum direct protection to the soil and at the same time create and

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Contour terraces retain snow in level furrows so that moisture and soil are not lost by run-off and erosion when the thaw sets in. Kansas.

Large-scale, co-operative soil conservation in Texas. The use of each piece of land is planned in relation to soil climate and topography, and given suitable protection against erosion. Note the almost universal use of strip cropping and contour cultivation.

maintain a crumb structure. A crumb structure in the soil may be said to have the same effect as a terrace in that it stops water from moving downhill, though it does so by absorption, so that water is not only rendered harmless as an eroding agent, but also is available for later plant growth. Though soil-conserving cropping systems which create crumb structure differ from environment to environment, they all have in common the use of grass—if grass can be made to grow—as a main crop.

Grass holds a unique position as a soil-conserving crop. A thick sward not only gives excellent direct protection against rain and wind, but the living root system of grasses is the only known agent that will create a stable crumb structure in a structureless soil in the course of two or three years. These soil-conserving virtues are fully utilised in a very simple system of cropping, known as contour strip cropping, which in one form or another is coming to be the basis of soil-conservation farming under widely different conditions. Grassed strips and cultivated strips are laid out alternately on the contour, and after a few years the grassed strips are ploughed up and the cultivated strips are put down to grass. The soil under grass is protected from erosion, and its structure and fertility are built up. It is found that under most conditions a good structure can be produced in two to three years, and will persist under cultivation for the same length of time. Contouring gives additional protection. Contour strip cropping has proved itself to be a most efficient way of controlling erosion under a rotation agriculture that maintains soil fertility, but for a variety of reasons it is not always applicable or does not fit into the established economic and social order. An essential pre-requisite of every successful soil-conservation system is that it must pay, and, as a corollary, that it must be freely acceptable to the people who have to operate it.

There are great areas of natural grassland, in Australia, America, Africa and India, where persistent overgrazing has destroyed the grass cover and stock trampling has destroyed the unprotected soil structure, with the result that serious erosion has occurred without the land ever having been cultivated. These lands are mostly in arid regions and are of low stock-carrying capacity, and there is a great tendency for occupiers to stock up to the enhanced capacity of a moist year and to pay the penalty of overstocking in subsequent dry years. The only solution is strictly to regulate grazing to what the land can bear—often a matter attended by insuperable social difficulties.

Wind erosion, which can be just as damaging as water erosion, is more difficult to control, because it is harder to stop wind from blowing across a plain than to stop water from running downhill. Much can be done, however, by planting tree and shrub windbreaks and, as with water erosion, by maintaining a good structure in the soil because soil crumbs do not blow about easily. Methods of 'stubble mulching', in which crop stubbles are not ploughed in but left to die and decay on the surface, have recently been found most effective against both wind and water erosion. The surface soil not only gets additional vegetative protection from the standing stubble, but its structure is preserved by the humus produced when the stubble decays. The excessive claims made for so-called 'ploughless' farming must, however, be regarded with caution.

All these measures of soil conservation present few difficulties in their separate applications. The difficulties arise when each piece of land is treated according to its requirements, and many treatments have to be integrated into a workable agricultural system that pays and is acceptable to the farmers. Effective soil conservation requires detailed planning of land utilisation in which land users must take a direct part, and for which active co-operation between land users to produce a unified plan is essential. The Americans have gone far in introducing planned, co-ordinated soil conservation on a large scale and have had some dramatic successes. Their experience shows that science has now largely mastered the physical problem of how to stop water from running downhill, but that there still remain many human problems connected with getting people to stop it for themselves. Until these problems have been solved soil erosion will continue to spread. They are problems of economics and social administration rather than of physics and chemistry. The new and immature science of soil conservation is rapidly becoming a branch of sociology.

The Russians entered the field of soil conservation later than the Americans who pioneered the way for the rest of the world. They have recently taken up soil conservation as a matter of great national urgency, and have approached the task in a very forthright way. In 1948 the Central Committee of the Russian Communist Party announced the details of a gigantic plan for conquering drought and soil erosion in the arid steppe region of south-east Russia. The region embraces about half a million square miles of land, and has a low (10–20 inches) and very uncertain rainfall. The plan requires the putting into practice throughout the region of complete agricultural systems, worked out in considerable detail on paper, that it is claimed will in 15 years abolish the hazards of drought and soil erosion, and make the land stable and productive.

The basis of the whole plan is the creation in the soil of a stable crumb structure to absorb moisture and resist erosion. This is to be achieved by the compulsory adoption of ley farming (arable rotations including grass) in place of the hitherto prevalent grain-fallow agriculture, supplemented by an intensive programme of water conservation by storage in natural and artificial ponds and by special measures of snow retention on the fields, by irrigation, and by a remarkable system of planted forest shelterbelts stretching north and south across the steppes at intervals of 30 miles, and east and west at intervals of 60 miles. The Russians believe that these shelterbelts will not only check wind erosion (though experience elsewhere is that their effect is limited to a distance of about a hundred yards from the shelterbelts) but also increase the general moistness of the climate. Probably their chief effect will be in improving snow retention. Thousands of miles of them are to be planted compulsorily by the collective farmers. If the plan succeeds—as yet there is no evidence whether it will or not—it will be a tremendous vindication of the Russians' faith in their soil scientists (though perhaps not quite so good for the scientists if it fails), for it will have been the first time in history that a large-scale reclamation scheme will have been carried out entirely on a basis of soil-science theory.

READING LIST

The Rape of the Earth (Faber, 1938), by G. V. Jacks and R. O. Whyte. *Soil Conservation* (McGraw Hill, 1939), by H. H. Bennet. *Deserts on the March* (Routledge and Kegan Paul, 1949), by Paul B. Sears. *The Practice of Soil Conservation in the British Colonial Empire* (Commonwealth Bureau of Soil Science, 1949), by Sir H. A. Tempany. *Soil Conservation* (F.A.O Washington, 1948).

Far and Near

Synthetic Pyrethrum

USED for more than a century in sprays and insect powders, the natural insecticide, pyrethrum, has held an unrivalled position. Its harmlessness to higher animals and its very rapid lethal effects upon insects has not been challenged by DDT or other synthetic materials. Japan and Kenya are major producers.

The insecticidal properties of pyrethrum were long attributed to two complex esters, pyrethrin I and pyrethrin II. American research isolated two other toxic esters in 1948, now known as cinerin I and cinerin II. All four of these substances are closely related. Crude pyrethrum flowers, as harvested and dried, contain just over 1% of these esters, and the crude flowers are extracted to produce pyrethrum insecticides containing about 20% of the toxic ingredients.

In 1949 U.S. Department of Agriculture research workers announced that they had synthesised an isomer of cinerin I. This material was found to be about as insecticidal as the natural ester. They then made slight chemical modifications to this synthetic molecule, and the substance then obtained was more powerfully insecticidal than cinerin I; indeed, it was claimed to be as effective as all four combined esters of pyrethrum.

In rather less than twelve months, this laboratory synthesis has been developed to the factory stage, and at least one U.S. chemical company is now producing the material on a commercial scale. The new insecticide has been given the name, *allethrin*. Chemically, it is the allyl homologue of a stereo-isomer of cinerin I. It is not a truly synthetic pyrethrum, therefore, but all reports show that it possesses at least an equivalent toxicity to insects. In the United States the synthetic product is selling at 10% to 15% less than natural pyrethrum.

Coal Tar Research Association

THE laboratories of the Coal Tar Research Association, Oxford Road, Comersal, near Leeds were opened by Sir John Anderson on May 12. At a subsequent luncheon at the Queen's Hotel, Leeds, speeches were made by Sir John Anderson and Dr. E. V. Evans, President of the Coal Tar Research Association.

Guide to Better Scientific Writing

A PAMPHLET which should lead to an improvement in the manner in which scientific papers and articles are written has been produced by a sub-committee of the Royal Society under the chairmanship of Prof. G. L. Brown, F.R.S. It is entitled *General Notes on the Preparation of Scientific Papers*, and is published by Cambridge University Press at 2*s*. 6*d*.

Obituaries

THE death occurred on May 4 of DR. HERMAN SHAW, director of the Science Museum, at the age of 58.

PROFESSOR G. W. ROBINSON, F.R.S., a leading expert on soil science, died at Bangor on May 6, aged 61. He was Professor of Agricultural Chemistry and adviser in the School of Agriculture in the University College of North Wales at Bangor.

Human Physiology for Schools

A VALUABLE little booklet by Richard Palmer has been published by the British Social Hygiene Council, Tavistock House, North Tavistock Square, W.C.1. It is entitled *Human Physiology as a Practical Subject in School*, and costs one shilling. It is concerned to describe a large number of simple scientific observations and experiments that students can make of the structure and functioning of their own bodies. Whilst intended primarily for the school-teacher these suggestions will be of considerable assistance to any one engaged in teaching biology to adults.

Transporting Radio Isotopes by Air

A METHOD has been devised for carrying radioactive isotopes in the wing tips of certain South African Airways aircraft flying from London Airport to South Africa. In these aircraft a felt-lined compartment with a hinged lid painted bright red has been provided in one of the wing tips. The isotopes will be carried in this compartment packed in a metal cylinder, four inches long by one and a half inches in diameter, of sufficient strength to survive accidents. The cylinder has a screw-on top to which is attached a ring for use when the cylinder has to be placed in or removed from the compartment. A three feet length of rod with a hook is used for this purpose. This method of air transport makes it possible to meet, without elaborate and weighty packaging of the isotopes, the British transport regulation that radio isotope consignments with the maximum permitted radiation (100 milliroentgens per hour) must be kept more than three feet away from human beings and livestock.

Film about Supersonic Flight

THE film *Faster than Sound* provides a dramatic contrast to the recent C.O.I. production *Wonders of the Deep* in that instead of witnessing a fascinating underwater drama, on this occasion we are taken up to 30,000 ft. to watch experiments in the development of the Supersonic Rocket.

It tells the dramatic story of research carried out by the Research and Development branch of the Ministry of Supply, experiments which, at first unsuccessful, eventually proved that a level flight of 600–800 m.p.h. through the dangerous sonic 'barrier' was a practical possibility.

The experiment, which was carried out in the region of the Scilly Isles, involved the making of a 11-ft. model of a pilotless machine to be propelled by rockets, automatically controlled, and designed to travel at a far higher speed than that so far achieved by full-size aircraft. The actual speed attained by the model proved to be in the region of 900 m.p.h. The completed model was carried up to 30,000 ft. by a parent Mosquito, released at that height and followed visually by an observer in a Gloster Meteor whilst in addition the flight was traced from a Cornish airfield by radar.

The film gives a clear and fascinating picture of the whole process; we see the completion of the model and the aircraft taking off on the experimental flight. The photography by cameraman Denny Densham is brilliant, and there is a factual commentary spoken by Sir Ralph Richardson. The film was directed by Diana Pine, runs for ten minutes and is obtainable on free loan from the Central Film Library.

Night Sky in July

The Moon.—New moon occurs on July 15d 05h 05m U.T., and full moon on July 29d 04h 17m. The following conjunctions with the moon take place:

July				
4d 03h	Jupiter in conjunction with the moon	Jupiter	1°	N.
12d 12h	Venus ,,	Venus	6°	S.
19d 08h	Saturn ,,	Saturn	0·8	N.
21d 18h	Mars ,,	Mars	1	N.
31d 09h	Jupiter ,,	Jupiter	0·9	N.

The Planets.—Mercury is a morning star in the early part of the month and is in superior conjunction on July 11, but throughout July it is too close to the sun to be seen. Venus is a morning star, rising at 1h 55m, on July 1 and only ten minutes later on July 31. At the end of the month more than 0·88 of the illuminated portion of the disk is visible and a pair of binoculars shows the planet like the moon when nearly full. Mars sets at 23h 40m on July 1 and 22h 05m on July 31. In the early part of the month the planet is a little S. of the star γ Virginis and towards the end of the month it is close to the bright star α Virginis, generally known as Spica. Jupiter rises at 22h 55m on July 1 and 2 hours earlier at the end of the month and can be seen until a little before sunrise. The planet is a little S.W. of λ Aquarii in the early part of July and recedes from it in a W. direction throughout the month. Saturn sets at 23h 10m and 21h 15m at the beginning and end of July, respectively, and as the latter occurs less than an hour after sunset the planet is then badly placed for observation.

The bright star Spica about which something was said in connexion with its close approach to Mars towards the end of July can be otherwise identified by drawing a line through α and γ Urs. Maj. or through the first and third stars of the Plough and prolonging it seven times the distance between these two stars; the line will pass close to Spica. This star is of a bluish-white colour and except for its brightness has no very outstanding features even if viewed through a telescope. But it is an interesting star when examined by means of the spectroscope because this has revealed the fact that it is a 'spectroscopic binary'. Its companion is about 6 million miles from the brighter

star and the two revolve around their common centre of gravity in four days.

The Royal Society Elects an Historian

UNDER the Statute of the Royal Society which provides for the election of persons who either have rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society, Dr. G. M. Trevelyan, O.M., has been elected a Fellow of the Society.

Another Atomic Spy Case

AN American scientist, Harry Gold, a research chemist employed by the City of Philadelphia in the general hospital there, has been arrested in America. He has been accused of receiving atomic bomb secrets from Dr. Klaus Fuchs, who was sentenced to 14 years' imprisonment in March at the Old Bailey, in 1944 and 1945 and turning them over to Russian agents.

Dr. Fuchs has been interviewed in prison by F.B.I. agents, and other people he had contact with in America are likely to be arrested.

Fuch's Successor

PROFESSOR M. H. L. Pryce, Wykham Professor of Physics at Oxford, has taken over temporarily the technical supervision of the Theoretical Physics Division of the Atomic Energy Research Establishment at Harwell. No permanent successor to Dr. Klaus Fuchs has yet been found and Professor Pryce is spending half a day each week at Harwell. In September he is leaving for Princeton for nine months as a visiting professor.

Foamed Latex

A READER has drawn our attention to an inaccuracy in the article "Foamed Latex" on pp. 134-35 of the April 1950 issue, which we regret particularly in view of the fact that we supplied a proof for the experts of the Dunlop Rubber Co. Ltd. to check. After receiving this reader's letter, we forwarded a copy of it to the Company and asked them to recheck the article.

After reading the article this second time the Company find the following correction to be necessary. "It is said in the article that the rubber latex is coagulated with acetic acid and then frothed with soap and stabilised with a gelling agent. Actually acetic acid is not used in the process and, of course, coagulation produces a tough lump of rubber which could not be frothed. Further, the gelling agent is not a stabiliser but, as its name indicates, causes the latex to gel by its de-stabilising action. The foamed latex process is superficially quite simple, although in actual fact very complex processes of a physico-chemical nature are involved. The liquid latex mix is first converted to a foam by beating with a little soap and, when the appropriate density of foam is reached, the gelling agent is mixed in. An essential characteristic of the gelling agent is that its action is delayed for a period of time, which can be adjusted according to such conditions as the temperature and alkalinity, and so gives time for the liquid froth to be poured into the mould where it will set or gel a few minutes later. By heating the mould and its contents, the wet gel is vulcanised to a strong and resilient product enabling it to be handled without damage or deformation. The article also says that it is the gelling agent which affects the ratio of rubber to air in the foam. This is not so. In fact, it is the degree of beating to which the latex is submitted which determines the foam density; the longer the beating is carried on, the more air is whipped in and consequently the lower the foam density."

Prof. M. H. L. Pryce

While we regret this error, we would emphasise that every possible precaution was taken by our editorial office to ensure accuracy in this particular case.

Correction

THERE was a misprint in the note on The Candela (May issue, p. 140); absolute zero is $-273°$C., and not, of course, $-270°$C. In the same issue some readers appear to have been confused as to melting point of gallium; this is 30°C.

A.Sc.W. Membership Declines

LATEST membership figure for the Association of Scientific Workers, published in the 1950 report of the executive committee, is 14,313. At the end of 1948 the A.Sc.W. had 15,521 members.

Among the resolutions before the A.Sc.W.'s annual meeting, held in London on May 20-21, was one condemning the French Government for dismissing Joliot-Curie from his post as High Commissioner of Atomic Energy (see DISCOVERY, June 1950, p. 202). This was carried by 89 votes to 29, with 31 abstentions. The recording of the votes of abstainers is unusual at these meetings, but the abstainers insisted that it should be done.

Joliot-Curie: Echoes in London and Moscow

A MEETING to protest at Joliot-Curie's dismissal was held in London on May 21. It was organised by the Cambridge Scientist Anti-war Group, the British Peace Committee and the International Women's Day Committee. Dr. W. A. Wooster, secretary of the Association of Scientific Workers, presided, and the speakers included Professor J. D. Bernal, who claimed that more and more military pressure was being put on scientists, and that those who publicly refused to apply their work for aggressive war would not be allowed to continue their scientific activities. "This trend, already a commonplace in the United States, has now begun in Britain and France," he said.

In Moscow the Soviet Peace Committee issued a statement expressing "profound indignation at the persecution to which the French Government is subjecting Academician Frederic Joliot-Curie—Chairman of the Permanent Committee of the World Peace Congress and Nobel Prize Winner. This greatest humanist and courageous fighter for world peace throughout many years of his scientific activity has repeatedly stated that the utilisation of atomic energy for peaceful purposes would unfold magnificent perspectives before humanity. When the warmongers began to utilise the discoveries of atomic physics for the criminal ends of the preparation of a new war, Joliot-Curie, as a genuine progressive scientist of our time, understood that he 'must fight in the ranks of those who desire that the achievement of science should be utilised for peaceful purposes and not for the self-seeking purposes of plunderers, not for precipitating war.'"

The Soviet Peace Committee sent Joliot-Curie "its most ardent and hearty greetings and expresses its admiration at his unbending determination to struggle against the threat of a new shambles".

Ventilation in Cinemas

MEASUREMENT of carbon dioxide content of the air can be used to determine whether cinemas and theatres are adequately ventilated. This point was made by J. F. Clark, F.R.I.C., in a recent lecture to the Society of Public Analysts. He described the results of an investigation carried out to test the adequacy of the conditions laid down in theatre licences regarding ventilation. Theatres and cinemas were inspected at peak periods. Temperatures, humidities and carbon dioxide concentration were determined at several points in each. It was found that temperature and humidity varied more with weather conditions than with the internal atmosphere, but the carbon dioxide content of the air gave a reliable indication of the ventilation. "Stuffiness" was apparent to the observer at a carbon dioxide level of 15 to 20 parts per 10,000.

A rapid method of sampling and testing for carbon dioxide concentration, accurate to 0·2 part per 10,000, was developed.

With most systems of ventilation it was considered that the usual requirements of a maximum of 10 parts per 10,000 was too stringent, since to maintain this level near draught screens and in high balconies an air supply was required which produced pronounced draughts in the more open parts of the auditorium. Ventilation giving a maximum of 15 parts in the least ventilated areas resulted in an average concentration of under 12 parts throughout the auditorium, and this could be maintained by any efficient ventilation system without producing noticeable draughts.

The Bookshelf

Colours and How We See Them. By H. Hartridge (London, Bell & Sons, 1949, pp. 158, 15*s*.).

Recent Advances in the Physiology of Vision. By H. Hartridge (London, Churchill, 1950, pp. 401 with 236 illustrations, 25*s*.).

PROFESSOR HARTRIDGE is nothing if not an enthusiast, and these books bear ample witness to his abounding interest in the subject of colour vision.

Colours and How We See Them is the embodiment of his 1946 Christmas Lectures at the Royal Institution; there is no doubt that the original lectures were vastly appreciated by their juvenile audience but it is a little doubtful whether this book will make the same appeal to the lay reader, for the written word, in a subject of this kind, can never rival the well illustrated lecture. But the book does contain an unrivalled collection of recipes for the production of striking demonstrations of the manifold phenomena of colour vision. From the simple repetition of Newton's classical experiments to the bizarre illusions generated by 'Bidwell's Top' and 'Benham's Ghost'; all are described in sufficient detail for their reproduction in any lecture theatre with a minimum of equipment.

The book is excellently produced, and makes the most intelligent use of a simple colour printing technique that the reviewer has yet seen.

In *Recent Advances in the Physiology of Vision* Professor Hartridge is writing for the scientific reader. He provides an excellent survey of the subject in the light of the considerable advances which have been made in the last four years.

C. G. A. H.

Practical Invertebrate Anatomy. By W. S. Bullough. (Macmillan, London, 1950; pp. 463, 168 illustrations, 28*s*.)

TEXTBOOKS of intermediate practical Zoology are relatively common, but the advanced student has hitherto been left to find his way without such assistance. It would appear that the magnitude of the task has been such as to deflect the efforts of those who might have attempted it towards the lower and less intensive levels of study. Before opening his book, therefore, one feels compelled to salute Dr. Bullough for his courage and endeavour.

On opening the book, one finds in the table of contents a measure of the task undertaken. It is no less than this—to provide practical instructions for the study of 122 genera belonging to over a hundred orders, and ranging from the Protozoa to the acraniate Chordata. As the author observes in his preface, the necessity for keeping the size of the book within bounds has caused him to limit himself to "those features which can be demonstrated in whole specimens of adult animals"—which means that information concerning thin sections, and young or larval forms has had to be excluded from the work. This is a very great pity, but it is preferable to the alternative of reducing the number of genera studied.

The method of treatment deserves mention here. Each phylum is allotted a chapter which opens with an outline of the characteristics of the phylum, followed by those of the class and order. The section devoted to each genus commences with a general account (including details of distribution, ecology, development, phylogeny, etc.), followed by practical instructions for investigating the external and internal anatomy. Under the heading of "Conclusion" suggestions are then made for special observations and comparative studies. Finally there is a list of references to papers giving more detailed information on the genus. Each genus is illustrated at least once by labelled line drawings which, while showing showing the true outline, represent details in a simplified and semi-diagrammatic manner. These drawings are of exceptional merit and, in a sense, form the foundation of the book. Each chapter ends with an appendix giving information on culturing, fixing, storing and preparing specimens for examination.

Dr. Bullough embarked upon this work while he was in Canada, and completed it in England. The genera dealt with are thus for the most part readily obtainable both here and in North America. The book will therefore be of service to advanced students on both sides of the Atlantic as a companion volume to any of the standard texts on the Invertebrates.

R. P. H.

The Natural Philosophy of Plant Form. By Agnes Arber. (London, Cambridge University Press, 1950, pp. 247, 46 sets of text-figures, 25*s*.)

DR. ARBER'S book is a philosophical exposition of the morphology of the higher plants, ranging from the Greeks to the present day. It is not easy to read, for it is the concentrated essence of much thought on plants and on what has been written about plants, underlain everywhere with philosophical ideas not always familiar to working botanists. All readers who already have a good knowledge of botany will find the work informative and productive of meditation. The valuable factual content of the book supports even more valuable theoretical developments, these in turn exhibiting points of view often disregarded nowadays, when the symmetrical growth of botany as an organised body of knowledge is hindered by the enormous accretion of details. Dr. Arber shows that the study of plant morphology is by no means an exhausted subject: her book may lead those who seek to explain the living plant in terms of chemistry and physics, to pause and think again.

B. BARNES.

The Elements of Genetics. By C. D. Darlington and K. Mather. (London, George Allen & Unwin Ltd., 1949, pp. 446, 25*s*.).

THIS book is a necessity for the teacher and for the biologist who specialises in other fields but who wishes to be up to date concerning the biology of inheritance. The authors have attempted to represent the whole scope of genetics, and have not hesitated to venture into speculation where this seems to them profitable.

Account is given of many topics still otherwise only described in research publications. In addition to a fresh presentation of the commoner facts of genetics the reader will find an outline of the cytoplasm-chromosome relationship and its bearing upon gene reduplication, an account of the polygenetics of characteristics showing continuous variation, and a description of the various known breeding systems and the part they play in regard to variability and to evolutionary changes brought about by selection. Evidence for plastogenes and plasmagenes, particulate cytoplasmic factors of inheritance, is described and the wider implications of their recognition are followed up. Theories that may help to elucidate the nature and origin of viruses in relation to genes are brought forward in this connexion.

Though no reference is made to Lysenko, the reader gradually becomes aware of the degree to which neo-Mendelian genetics has forestalled many of his criticisms by prior investigation and by provision for the incorporation of the ascertained facts into the general theory. The cases of certain graft hybrids and the dauermodifications of Jollos are good examples of this.

The devotion of only one chapter to man and mankind is misleading concerning the relevance of this book to human affairs. Matters important for the well-being, and for the understanding of man are dealt with throughout the book in various contexts.

It is unfortunate that some parts of the book are not more lucid. At times abbreviation has been taken too far. However, at the end there is a useful 51-page glossary of genetical terms.

M. H. C.

Industrial Nutrition. By Magnus Pyke, B.Sc., Ph.S., F.R.I.C. (London, Macdonald & Evans, 1950, pp. 212, 10*s*.)

ONE of the greatest problems during the war was to economise on shipping used for purposes other than actual materials necessary for war. It was therefore essential to reduce to a bare minimum that required for the transport of food. Fortunately, unlike the 1914–18 war, the Government of the day was in receipt of expert scientific and medical advice on the nutritional problems concerned with rationing, and the ration level was never cut below the minimum required for physical efficiency. The industrial workers represented a highly important class of the population from the nutritional point of view in wartime because their output was directly related to the adequacy in quantity and quality of their food intake. A great deal of attention was paid therefore by the Ministry of Food to this particular problem and Dr. Pyke was obviously in a position while he was with the Ministry to make a special study of the subject. His book can be regarded therefore as

authoritative. A glance through the contents list shows that it is certainly comprehensive, and a perusal of the pages shows that the style is pleasant and the material factual and well-documented. This book should be read and studied not only by industrial medical officers and those concerned with factory feeding but also by dieticians of all types and by those who have a general interest in nutrition and physiology. It would be of great value as general reading for a medical student.

GEOFFREY H. BOURNE.

Reflections of a Physicist. By P. W. Bridgman. (New York, Philosophical Library, 1950, pp. 388, 5 dollars.)

PROFESSOR BRIDGMAN, in the course of his work as a professional physicist, developed an attitude of mind called operationalism and applied it to many different fields including psychology, sociology and religion. He disclaims any esoteric or general 'philosophical' significance for the term; such an interpretation would be against this concrete down-to-earth attitude towards the world around him.

The fruits of twenty years of his thinking on a variety of topics are presented in this book. The pieces include after-dinner speeches and addresses to societies as well as contributions to periodicals such as *Harper's Magazine*, *Science*, and *The Scientific Monthly*. Three are published here for the first time. Titles include "The Time Scale", "Scientists and Social Responsibility," "Science and Freedom", and "The Prospect for Intelligence", all of which show the range of the author's interest. Every piece has the stamp of intellectual penetration and courage; the author appears as shrewd, realistic, and modest.

The technique dubbed operationalism first came to Professor Bridgman, as he admitted in discussion recently at a meeting in London, many years ago when a very bright young man at the university lectured on dimensional analysis, claiming it to be the means of solving almost everything. This so shook the young Bridgman, who began to wonder if, after all, his meticulously contrived and difficult experimental work was to be wasted, that he set to work to think his way right through the subject. As a result he found out the assumptions involved. His analysis led to the general rule that the only way to get at the truth was to analyse each situation and become aware of *all* the factors involved, not forgetting scientific fashion and belief. Each concept had to be checked for its meaning, and it was meaningless if it did not lead to an operation, an activity. In this way he became quick at detecting "absolutes and supernaturals and verbalisms". He admitted some verbalisms as useful and the existence of purely mental operations or experiments. He distinguished "paper-and-pencil" operations.

This, crudely simplified, is operationalism. It is clearly not a hard technique to be learned from a book; it has to be practised with concentration on each situation as it arises. It could be described as the rigorous and courageous application of high intelligence, and it has influenced considerably the author's attitude towards many problems outside the realm of physics.

It is not easy to quote from the book because the whole of each essay is a thing in itself and ought to be quoted in its entirety. Nevertheless, to show what is to be found in many places, three quotations can be given. The first is: "It is something of a shock to the enthusiastic and unsophisticated physicist who thus rushes to the social attack to discover how very often the practices and demands of society are positively inimical to the exercise of intelligence." The second is: "Not many people like to use their minds, and there is always some spontaneous hostility of those who do not like to think towards those who do." And the third: "Several of the contributors (to a symposium) have referred to science as of necessity being public in character; I believe on the other hand that a simple inspection of what one does in any scientific enterprise will show that the most important part of science is private." This last is enough of a surprise for any intelligent person to realise that he should lose no time in getting acquainted with the opinions of Professor Bridgman.

C. L. BOLTZ.

Science, Servant of Man. A Layman's Primer for the Age of Science. By I. Bernard Cohen. (London, Sigma Books, 1949, pp. 358, 7 illustrations, 15*s.*)

THERE is, of course, no easy road to being scientifically literate: Cohen's book can no more make you a scientist than the Cambridge History of English Literature can make you an English Scholar. Yet Cohen's subtitle is justified by the contents of his book and if he succeeds, as he ought, in making his non-scientific readers want to know more he will have achieved a worthwhile success. And at least they will learn how a scientist goes to work in fields as varied as radiophysics, agriculture, plastics and biochemistry. They will also find demonstrated that the 'happy accident' is only the beginning of a great deal that is quite the reverse of accidental; but that it can yield valuable results only if the 'total scientific situation' is suitable. This situation includes not only previous relevant discoveries but the co-existence of appropriate incentives.

The book is well written, scholarly and above all, interesting. It may need some courage on the part of the layman it is intended for if he is not only to buy it but to sit down and start reading it. But his courage will be well rewarded for having started to read he is likely to go on. It is a pity, however, that footnotes are not used instead of being collected together at the end of the book.

Mountains and Moorlands. By W. H. Pearsall. The New Naturalist, No. 11. (Collins, London, 1950, pp. 312, 47 coloured photographs, 34 black-and-white photographs, and 48 text figures, 21*s.*)

BOTANY, zoology, geology and soil science, seasoned with contributions from history and pre-history, are compounded by Professor Pearsall into a wonderfully satisfying and stimulating account of the results of thirty years of study of the British uplands. The abundant illustrations, coloured and plain, illuminate the text and arouse both admiration and desire.

The author has a remarkable story to tell. It could well be a depressing story, for it is much concerned with the degeneration of mountains, of soil and of populations. Mountains have gone down before frost, water and wind, soils have lost most of their fertility and populations, human, animal and plant alike, have fallen off in strength and variety. These changes have in part resulted from the wastage of the years, but, perhaps in greater part because man, not understanding the trend of events, has not even realised the need that he should attempt to stop the rot. In recent times especially, the down-grade changes have proceeded very rapidly indeed. But the story is not depressing. The author, with his deep, sensitive knowledge of his subject is neither pessimistic nor greatly alarmed. He seems satisfied that much of the damage that man has done, wittingly or unwittingly, can be repaired, and that well-managed control can lead to a substantial recovery: he suggests that, without loss of beauty and without harm to the wild populations, the mountains and moorlands can be led to make a much-needed contribution to the national economy. As these areas cover about one-third of the inhabitable parts of the British Isles, their importance is obvious.

In matter and in manner, *Mountains and Moorlands* is a treasure to the naturalist. It is of outstanding value as a source of information, but even more, it is an encouragement to all students of nature, for it is a triumphant demonstration of what can be made of botany and its allied sciences, when the maker has knowledge and insight, and builds on studies carried through in the open air.

B. BARNES.

Science German Course. By C. W. Paget Moffat, revised by Joseph Horne. (London, University Tutorial Press, 1950, pp. 311, 9*s.* 6*d.*)

THIS is the fourth edition of the fullest existent book of its type, now thoroughly revised and reset. Grammar, sentence construction, vocabulary, abbreviations, etc. make up about a quarter of the whole. The reading matter is up to date and includes sections on biology, zoology, and physiology, as well as the usual sciences. The only section that really dates is that on mathematics. Subjects covered in the physics section include cosmic rays, the new 'absolute' practical electrical units, nuclear physics, and the Pauli meson theory of nuclear forces, which gives a good idea of how up to date the reading matter is. In a fifth edition the reviser should consider including passages on psychology and philosophy, both of which are now studied by science students.

C. L. BOLTZ.

Printed and Published in Great Britain by Jarrold & Sons, Ltd., Norwich. *Editorial Offices: 244 High Holborn, W.C.1.*

Murder by Hormones

'Methoxone' is the proprietary name given to the sodium salt of 4-chlor-2-methyl-phenoxy-acetic acid. Its development at the Jealott's Hill Research Station of I.C.I. marked a revolution in the technique of weedkilling. 'Methoxone' represents the achievement of agricultural scientists probing the mysteries of plant growth. Growth in plants, as in animals, is controlled by minute secretions known as hormones. These are complex substances, but physiologists are now able to isolate them and to produce similar compounds artificially. In 1940 the Jealott's Hill biologists discovered that certain concentrations of plant hormones could hinder as well as assist growth. Some plants were more affected than others, and as many weeds of cornland were among these, it was at once seen that hormones held the possibility of selective weedkilling. The next step was to find a synthetic hormone with the maximum effect in retarding growth. Drs. W. G. Templeman and W. A. Sexton of I.C.I. undertook the necessary research. Of the many compounds which they produced and examined, 'Methoxone' gave greatest promise, and in nation-wide field trials, their laboratory results were amply confirmed.

Today, 'Methoxone' preparations, under the trade name 'Agroxone' can be obtained by farmers everywhere. Thus the age-old problem of the wheat and the tares has been brought a noteworthy step nearer solution.

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